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Microprocessor Peripherals UPI™ User's Manual

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MICROPROCESSOR PERIPHERALS
UPI™ USER'S MANUAL

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Introduction 1

CHAPTER 1
INTRODUCTION

Accompanying the introduction of microprocessors such as the 8080, 8085, 8088, and 8086 there has been a rapid proliferation of intelligent peripheral devices. These special purpose peripherals extend CPU performance and flexibility in a number of important ways.

Table 1-1. Intelligent Peripheral Devices

8255 (GPIO)	Programmable Peripheral Interface
8251A (USART)	Programmable Communication Interface
8253 (TIMER)	Programmable Interval Timer
8257 (DMA)	Programmable DMA Controller
8259	Programmable Interrupt Controller
8271 (SDFDC), 8272 (DDFDC)	Programmable Floppy Disk Controllers
8273 (SDLC)	Programmable Synchronous Data Link Controller
8274	Programmable Multiprotocol-Serial Communications Controller
8275/8276 (CRT)	Programmable CRT Controllers
8279 (PKD)	Programmable Keyboard/Display Controller
8291A, 8292, 8293	Programmable GPIB System Talker, Listener, Controller

Intelligent devices like the 8272 floppy disk controller and 8273 synchronous data link controller (see Table 1-1) can preprocess serial data and perform control tasks which off-load the main system processor. Higher overall system throughout is achieved and software complexity is greatly reduced. The intelligent peripheral chips simplify master processor control tasks by performing many functions externally in peripheral hardware rather than internally in main processor software.

Intelligent peripherals also provide system flexibility. They contain on-chip mode registers which are programmed by the master processor during system initialization. These control registers allow the peripheral to be configured into many different operation modes. The user-defined program for the peripheral is stored in main system memory and is transferred to the peripheral's registers whenever a mode change is required. Of course, this type of flexibility requires software overhead in the master system which tends to limit the benefit derived from the peripheral chip.

In the past, intelligent peripherals were designed to handle very specialized tasks. Separate chips were designed for communication disciplines, parallel I/O, keyboard encoding, interval timing, CRT control, etc. Yet, in spite of the large number of devices available and the increased flexibility built into these chips, there is still a large number of microcomputer peripheral control tasks which are not satisfied.

With the introduction of the Universal Peripheral Interface (UPI) microcomputer, Intel has taken the intelligent peripheral concept a step further by providing an intelligent controller that is fully user programmable. It is a complete single-chip microcomputer which can connect directly to a master processor data bus. It has the same advantages of intelligence and flexibility which previous peripheral chips offered. In addition, the UPI is user-programmable: it has 1K bytes of ROM or EPROM memory for program storage plus 64 bytes of RAM memory for data storage or initialization from the master processor. The UPI device allows a designer to fully specify his control algorithm in the peripheral chip without relying on the master processor. Devices like printer controllers and keyboard scanners can be completely self-contained, relying on the master processor only for data transfer.

The UPI family currently consists of five components:

- 8741A microcomputer with 1K EPROM memory
- 8041AH microcomputer with 1K ROM memory
- 8042 microcomputer with 2K ROM memory
- 8243 I/O expander device
- 8742 microcomputer with 2K EPROM memory

The 8741A, 8041AH, 8742 and 8042 single chip microcomputers are functionally equivalent except for the type and amount of program memory available with each. These devices have the following main features:

- 8-bit CPU
- 8-bit data bus interface registers
- 1K by 8 bit ROM or EPROM memory (2K for 8042/8742)
- 64 by 8 bit RAM memory (128 bytes for 8042/8742)
- Interval timer/event counter
- Two 8-bit TTL compatible I/O ports
- Resident clock oscillator
- 12 MHZ operation, 1.25 μsec instruction cycle for 8041AH, 8742, 8042

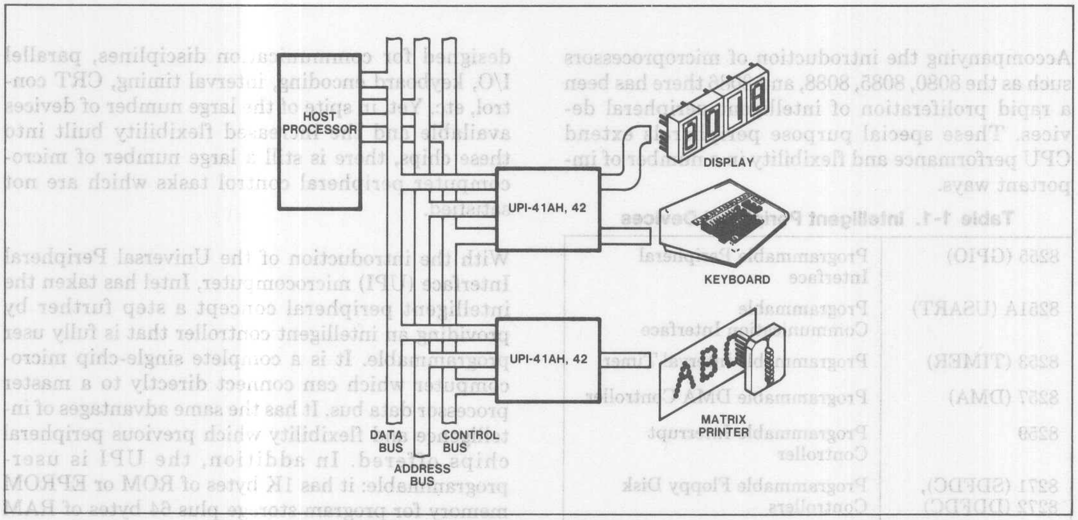


Figure 1-1. Interfacing Peripherals To Microcomputer Systems

HMOS processing has been applied to the UPI family to allow for additional performance and memory capability while reducing costs. The 8041AH, 8741A, 8042, 8742 are all pin and software compatible. This allows growth in present designs to incorporate new features and add additional performance. For new designs, the additional memory and performance of the 8042/8742 extends the UPI 'grow your own solution' concept to more complex motor control tasks, 80-column printers and process control applications as examples.

The 8243 device is an I/O multiplexer which allows expansion of I/O to over 100 lines (if seven devices are used). All three parts are fabricated with N-channel MOS technology and require a single, 5V supply for operation.

INTERFACE REGISTERS FOR MULTI-PROCESSOR CONFIGURATIONS

In the normal configuration, the 8041AH/8741A, 8042/8742 interfaces to the system bus, just like any intelligent peripheral device (see Figure 1-1). The host processor and the 8041AH/8741A, 8042/8742 form a loosely coupled multi-processor system, that is, communications between the two processors are direct. Common resources are three addressable registers located physically on the 8041AH/8741A, 8042/8742. These registers are the Data Bus Buffer Input (DBBIN), Data Bus Buffer Output (DBBOUT), and Status (STATUS) registers. The host processor may read data from DBBOUT or write commands and data into DBBIN. The status of DBBOUT and DBBIN plus user-defined status is supplied in STATUS. The host may read STATUS at any time. An interrupt to the UPI processor is automatically generated (if enabled) when DBBIN is loaded.

Because the UPI contains a complete microcomputer with program memory, data memory, and CPU it can function as a "Universal" controller. A designer can program the UPI to control printers, tape transports, or multiple serial communication channels. The UPI can also handle off-line arithmetic processing, or any number of other low speed control tasks.

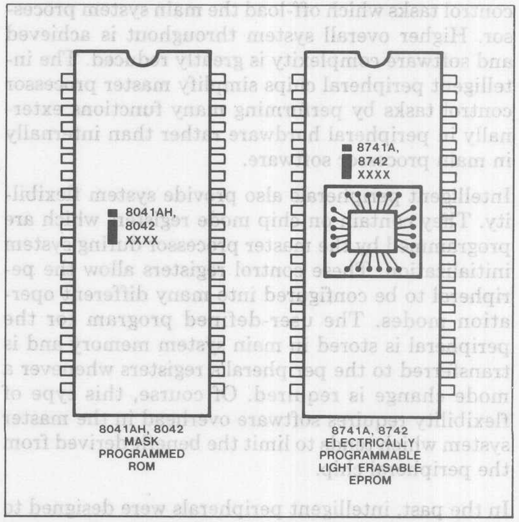


Figure 1-2. Pin Compatible ROM/EPROM Versions

POWERFUL 8-BIT PROCESSOR

The UPI contains a powerful, 8-bit CPU with as fast as 1.25 μsec cycle time and two single-level interrupts. Its instruction set includes over 90 instructions for easy software development. Most instructions are single byte and single cycle and none are more than two bytes long. The instruction set is optimized for bit manipulation and I/O operations. Special instructions are included to allow binary or BCD arithmetic operations, table lookup routines, loop counters, and N-way branch routines.

SPECIAL INSTRUCTION SET FEATURES

- For Loop Counters:
  Decrement Register and Jump if not zero.
- For Bit Manipulation:
  AND to A (immediate data or Register)
  OR to A (immediate data or Register)
  XOR to A (immediate data or Register)
  AND to Output Ports (Accumulator)
  OR to Output Ports (Accumulator)
  Jump Conditionally on any bit in A
- For BDC Arithmetic:
  Decimal Adjust A
  Swap 4-bit Nibbles of A
  Exchange lower nibbles of A and Register
  Rotate A left or right with or without Carry
- For Lookup Tables:
  Load A from Page of ROM (Address in A)
  Load A from Current Page of ROM (Address in A)

Features for Peripheral Control

The UPI 8-bit interval timer/event counter can be used to generate complex timing sequences for control applications or it can count external events such as switch closures and position encoder pulses. Software timing loops can be simplified or eliminated by the interval timer. If enabled, an interrupt to the CPU will occur when the timer overflows.

The UPI I/O complement contains two TTL-compatible 8-bit bidirectional I/O ports and two general-purpose test inputs. Each of the 16 port lines can individually function as either input or output under software control. Four of the port lines can also function as an interface for the 8243 I/O expander which provides four additional 4-bit ports that are directly addressable by UPI software. The 8243 expander allows low cost I/O expansion for large control applications while maintaining easy and efficient software port addressing.

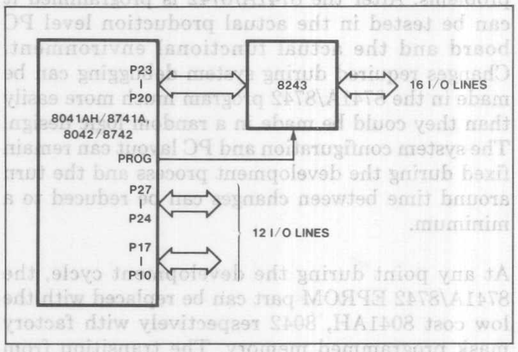


Figure 1-4. 8243 I/O Expander Interface

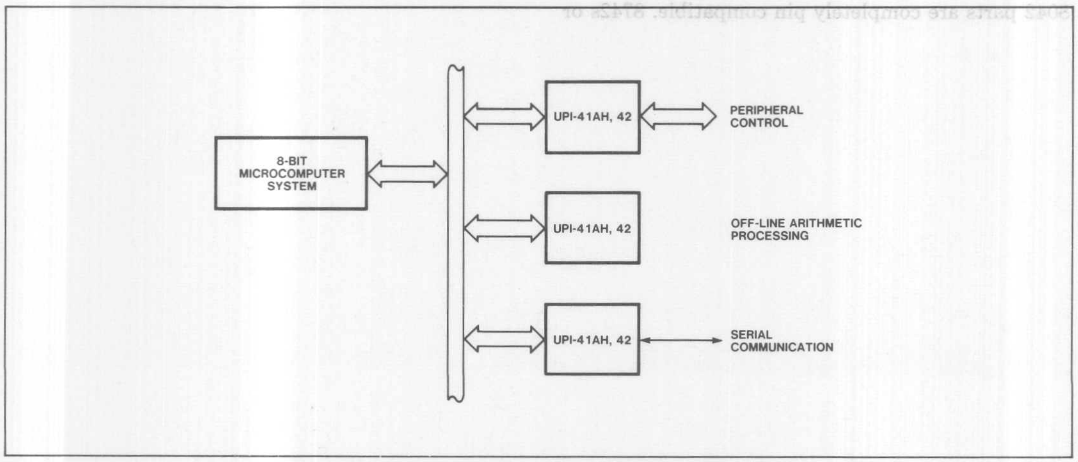


Figure 1-3. Interfaces And Protocols For Multiprocessor Systems

On-Chip Memory

The UPI's 64 (128) bytes of data memory include dual working register banks and an 8-level program counter stack. Switching between the register banks allows fast response to interrupts. The stack is used to store return addresses and processor status upon entering a subroutine.

The UPI program memory is available in two types to allow flexibility in moving from design to prototype to production with the same PC layout. The 8741A, 8742 device with EPROM memory is very economical for initial system design and development. Its program memory can be electrically programmed using the Intel Universal PROM Programmer. When changes are needed, the entire program can be erased using UV lamp and reprogrammed in about 20 minutes. This means the 8741A/8742 can be used as a single chip "breadboard" for very complex interface and control problems. After the 8741A/8742 is programmed it can be tested in the actual production level PC board and the actual functional environment. Changes required during system debugging can be made in the 8741A/8742 program much more easily than they could be made in a random logic design. The system configuration and PC layout can remain fixed during the development process and the turn around time between changes can be reduced to a minimum.

At any point during the development cycle, the 8741A/8742 EPROM part can be replaced with the low cost 8041AH, 8042 respectively with factory mask programmed memory. The transition from system development to mass production is made smoothly because the 8741A and 8041AH, 8742 and 8042 parts are completely pin compatible. 8742s or 8042s can be used in an 8041AH/8741 socket. This feature allows extensive testing with the EPROM part, even into initial shipments to customers. Yet, the transition to low-cost ROM is simplified to the point of being merely a package substitution.

PREPROGRAMMED UPI's

The 8292, 8294, and 8295 are 8041A's that are programmed by Intel and sold as standard peripherals. The 8292 is a GPIB controller, part of a three chip GPIB system. The 8294 is a Data Encryption Unit that implements the National Bureau of Standards data encryption algorithm. The 8295 is a dot matrix printer controller designed especially for the LRC 7040 series dot matrix impact printers. These parts illustrate the great flexibility offered by the UPI family.

DEVELOPMENT SUPPORT

The UPI microcomputer is fully supported by Intel with development tools like the UPP PROM programmer already mentioned. An ICE-41A in-circuit emulator is also available to allow UPI software and hardware to be developed easily and quickly. The combination of device features and Intel development support make the UPI an ideal component for low-speed peripheral control applications.

UPI DEVELOPMENT SUPPORT

- 8048/8041AH/8042 Assembler
- Universal PROM Programmer UPP Series
- ICE-41A Module
- MULTI-ICE
- Insite User's Library
- Application Engineers
- Training Courses

Functional Description 2

CHAPTER 2
FUNCTIONAL DESCRIPTION

The UPI-41AH, 42 microcomputer is an intelligent peripheral controller designed to operate in iAPX-86, 88, MCS-85, MCS-80, MCS-51 and MCS-48 systems. The UPI'S architecture, illustrated in Figure 2-1, is based on a low cost, single-chip microcomputer with program memory, data memory, CPU, I/O, event timer and clock oscillator in a single 40-pin package. Special interface registers are included which enable the UPI to function as a peripheral to an 8-bit master processor.

This chapter provides a basic description of the UPI microcomputer and its system interface registers. Unless otherwise noted the descriptions in this section apply to both the 8741A, 8742 (with UV erasable program memory) and the 8041AH, 8042 (with factory mask programmed memory). These two devices are so similar that they can be considered identical under most circumstances. All functions described in this chapter apply to the 8041AH, 8042, and 8741A, 8742.

PIN DESCRIPTION

The 8041AH/8741A, 8042/8742 are packaged in 40-pin Dual In-Line (DIP) packages. The pin configuration for both devices is shown in Figure 2-2. Figure 2-3 illustrates the UPI Logic Symbol.

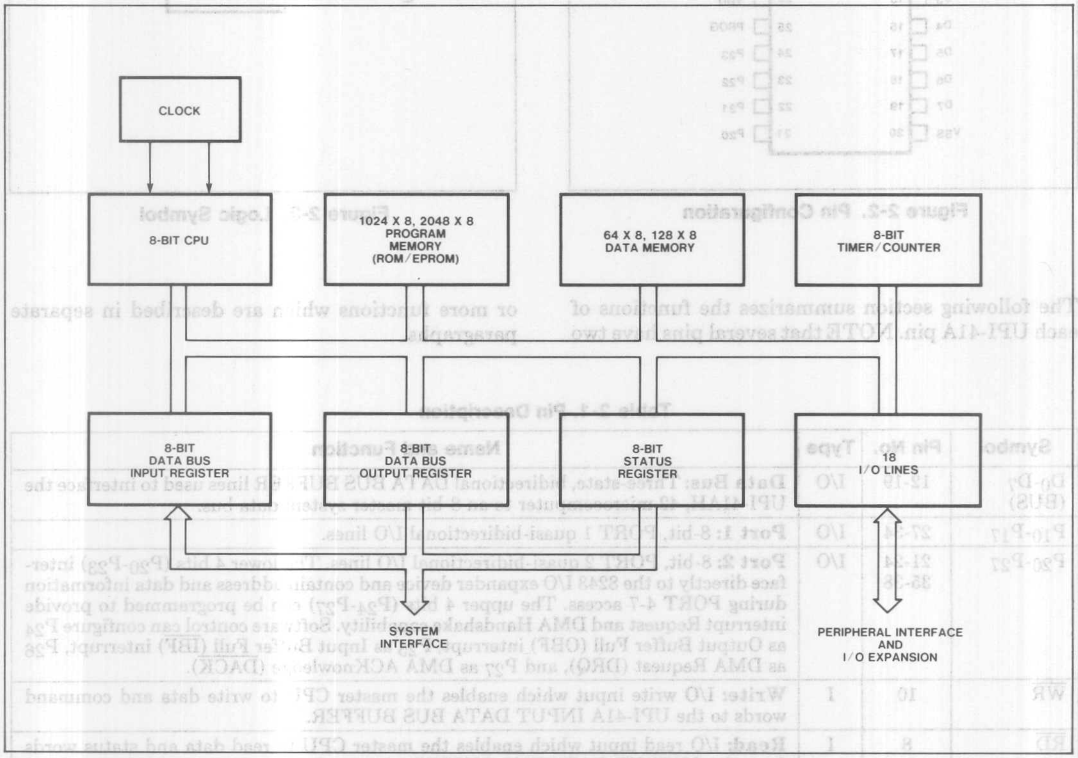


Figure 2-1. UPI-41AH, 42 Single Chip Microcomputer

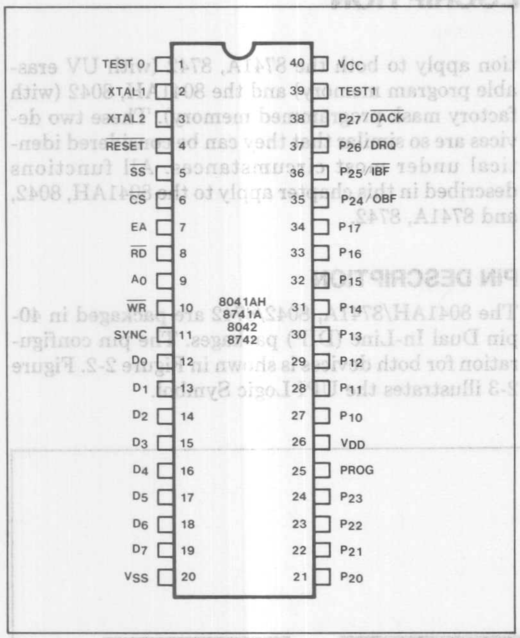


Figure 2-2. Pin Configuration

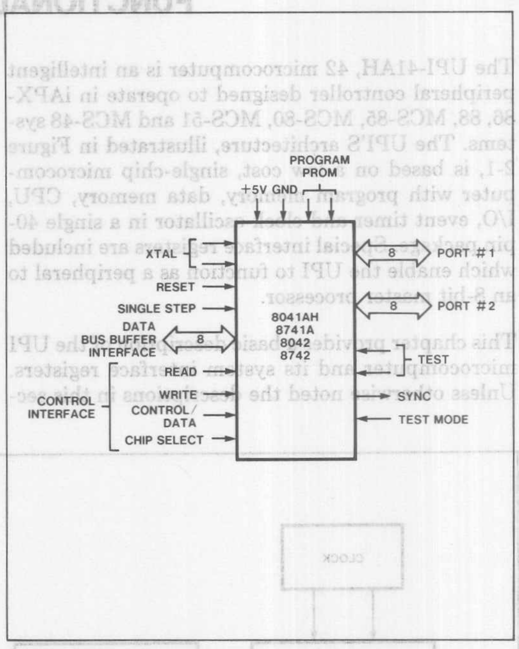


Figure 2-3. Logic Symbol

The following section summarizes the functions of each UPI-41A pin. NOTE that several pins have two or more functions which are described in separate paragraphs.

Table 2-1. Pin Description

Symbol	Pin No.	Type	Name and Function
D_0-D_7 (BUS)	12-19	I/O	**Data Bus:** Three-state, bidirectional DATA BUS BUFFER lines used to interface the UPI-41AH, 42 microcomputer to an 8-bit master system data bus.
P_{10}-P_{17}	27-34	I/O	**Port 1:** 8-bit, PORT 1 quasi-bidirectional I/O lines.
P_{20}-P_{27}	21-24 35-38	I/O	**Port 2:** 8-bit, PORT 2 quasi-bidirectional I/O lines. The lower 4 bits (P_{20}-P_{23}) interface directly to the 8243 I/O expander device and contain address and data information during PORT 4-7 access. The upper 4 bits (P_{24}-P_{27}) can be programmed to provide interrupt Request and DMA Handshake capability. Software control can configure P_{24} as Output Buffer Full (OBF) interrupt, P_{25} as Input Buffer Full ($\overline{IBF}$) interrupt, P_{26} as DMA Request (DRQ), and P_{27} as DMA ACKnowledge ($\overline{DACK}$).
$\overline{WR}$	10	I	**Write:** I/O write input which enables the master CPU to write data and command words to the UPI-41A INPUT DATA BUS BUFFER.
$\overline{RD}$	8	I	**Read:** I/O read input which enables the master CPU to read data and status words from the OUTPUT DATA BUS BUFFER or status register.
$\overline{CS}$	6	I	**Chip Select:** Chip select input used to select one UPI-41AH, 42 microcomputer out of several connected to a common data bus.
A_0	9	I	**Command/Data Select:** Address input used by the master processor to indicate whether byte transfer is data (A_0=0) or command (A_0=1).
TEST 0, TEST 1	1 39	I	**Test Inputs:** Input pins which can be directly tested using conditional branch instructions. **Frequency Reference:** TEST 1 (T_1) also functions as the event timer input (under software control). TEST 0 (T_0) is used during PROM programming and verification in the 8741A, 8742.

Table 2-1. Pin Description (Continued)

Symbol	Pin No.	Type	Name and Function
XTAL 1, XTAL 2	2 3	I	**Inputs:** Inputs for a crystal, LC or an external timing signal to determine the internal oscillator frequency.
SYNC	11	O	**Output Clock:** Output signal which occurs once per UPI-41A instruction cycle. SYNC can be used as a strobe for external circuitry; it is also used to synchronize single step operation.
EA	7	I	**External Access:** External access input which allows emulation, testing and PROM/ROM verification.
PROG	25	I/O	**Program:** Multifunction pin used as the program pulse input during PROM programming. During I/O expander access the PROG pin acts as an address/data strobe to the 8243.
RESET	4	I	**Reset:** Input used to reset status flip-flops and to set the program counter to zero. $\overline{\text{RESET}}$ is also used during PROM programming and verification.
$\overline{\text{SS}}$	5	I	**Single Step:** Single step input used in conjunction with the SYNC output to step the program through each instruction.
V_{CC}	40		**Power:** +5V main power supply pin.
V_{DD}	26		**Power:** +5V during normal operation. +25V during programming operation, +21V for programming 8742. Low power standby pin in ROM version.
V_{SS}	20		**Ground:** Circuit ground potential.

The following sections provide a detailed functional description of the UPI microcomputer. Figure 2-4 illustrates the functional blocks within the UPI device.

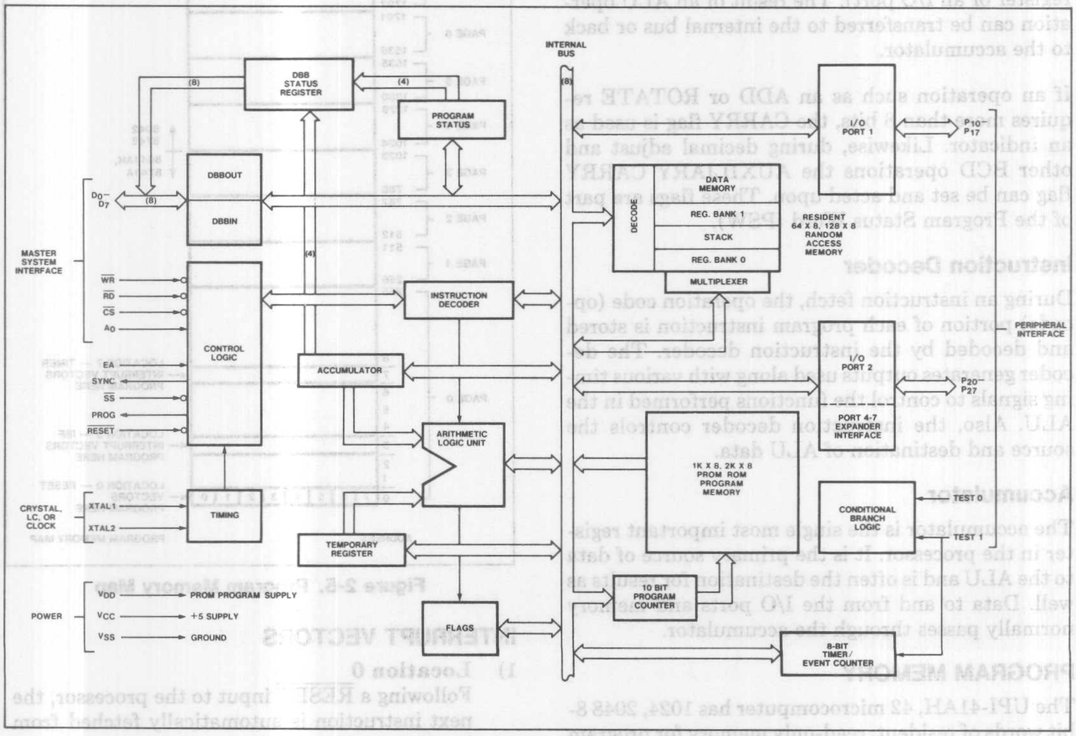


Figure 2-4. UPI-41AH, 42™ Block Diagram

CPU SECTION

The CPU section of the UPI-41AH, 42 microcomputer performs basic data manipulations and controls data flow throughout the single chip computer via the internal 8-bit data bus. The CPU section includes the following functional blocks shown in Figure 2-4:

- Arithmetic Logic Unit (ALU)
- Instruction Decoder
- Accumulator
- Flags

Arithmetic Logic Units (ALU)

The ALU is capable of performing the following operations:

- ADD with or without carry
- AND, OR, and EXCLUSIVE OR
- Increment, Decrement
- Bit complement
- Rotate left or right
- Swap
- BCD decimal adjust

In a typical operation data from the accumulator is combined in the ALU with data from some other source on the UPI-41AH, 42 internal bus (such as a register or an I/O port). The result of an ALU operation can be transferred to the internal bus or back to the accumulator.

If an operation such as an ADD or ROTATE requires more than 8 bits, the CARRY flag is used as an indicator. Likewise, during decimal adjust and other BCD operations the AUXILIARY CARRY flag can be set and acted upon. These flags are part of the Program Status Word (PSW).

Instruction Decoder

During an instruction fetch, the operation code (opcode) portion of each program instruction is stored and decoded by the instruction decoder. The decoder generates outputs used along with various timing signals to control the functions performed in the ALU. Also, the instruction decoder controls the source and destination of ALU data.

Accumulator

The accumulator is the single most important register in the processor. It is the primary source of data to the ALU and is often the destination for results as well. Data to and from the I/O ports and memory normally passes through the accumulator.

PROGRAM MEMORY

The UPI-41AH, 42 microcomputer has 1024, 2048 8-bit words of resident, read-only memory for program storage. Each of these memory locations is directly addressable by a 10-bit program counter. Depending on the type of application and the number of program changes anticipated, two types of program memory are available:

- 8041AH, 8042 with mask programmed ROM Memory
- 8741A, 8742 with electrically programmable EPROM Memory

The 8041AH and 8741A, 8042 and 8742 are functionally identical parts and are completely pin compatible. The 8742 and 8042 can be used in 8041AH, 8741A sockets. The 8041AH, 8042 has ROM memory which is mask programmed to user specification during fabrication. The 8741A/8742 are electrically programmed by the user using the Universal PROM Programmer (UPP series) with a UPP-848 or UPP-549 Personality Card. It can be erased using ultraviolet light and reprogrammed at any time.

A program memory map is illustrated in Figure 2-5. Memory is divided into 256 location 'pages' and three locations are reserved for special use:

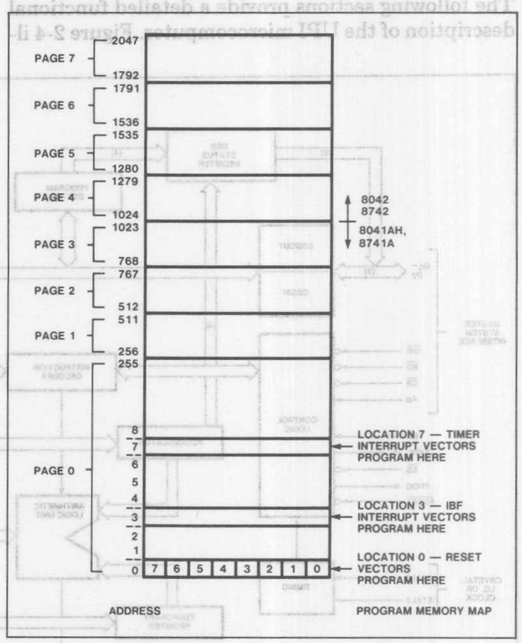


Figure 2-5. Program Memory Map

INTERRUPT VECTORS

1) **Location 0**

   Following a $\overline{\text{RESET}}$ input to the processor, the next instruction is automatically fetched from location 0.

2) **Location 3**
   An interrupt generated by an Input Buffer Full (IBF) condition (when the IBF interrupt is enabled) causes the next instruction to be fetched from location 3.

3) **Location 7**
   A timer overflow interrupt (when enabled) will cause the next instruction to be fetched from location 7.

Following a system $\overline{\text{RESET}}$, program execution begins at location 0. Instructions in program memory are normally executed sequentially. Program control can be transferred out of the main line of code by an input buffer full (IBF) interrupt or a timer interrupt, or when a jump or call instruction is encountered. An IBF interrupt (if enabled) will automatically transfer control to location 3 while a timer interrupt will transfer control to location 7.

All conditional JUMP instructions and the indirect JUMP instruction are limited in range to the current 256-location page (that is, they alter PC bits 0–7 only). If a conditional JUMP or indirect JUMP begins in location 255 of a page, it must reference a destination on the following page.

Program memory can be used to store constants as well as program instructions. The UPI-41AH, 42 instruction set contains an instruction (MOVP3) designed specifically for efficient transfer of look-up table information from page 3 of memory.

DATA MEMORY

The UPI-41AH, 42 universal peripheral interface has 64, 128 8-bit words of random access data memory. This memory contains two working register banks, an 8-level program counter stack and a scratch pad memory, as shown in Figure 2-6. The amount of scratch pad memory available is variable depending on the number of addresses nested in the stack and the number of working registers being used.

Addressing Data Memory

The first eight locations in RAM are designated as working registers R_0–R_7. These locations (or registers) can be addressed directly by specifying a register number in the instruction. Since these locations are easily addressed, they are generally used to store frequently accessed intermediate results. Other locations in data memory are addressed indirectly by using R_0 or R_1 to specify the desired address. Since all RAM locations (including the eight working registers) can be addressed by 6 bits, the two most significant bits (6 and 7) of the addressing registers are ignored.

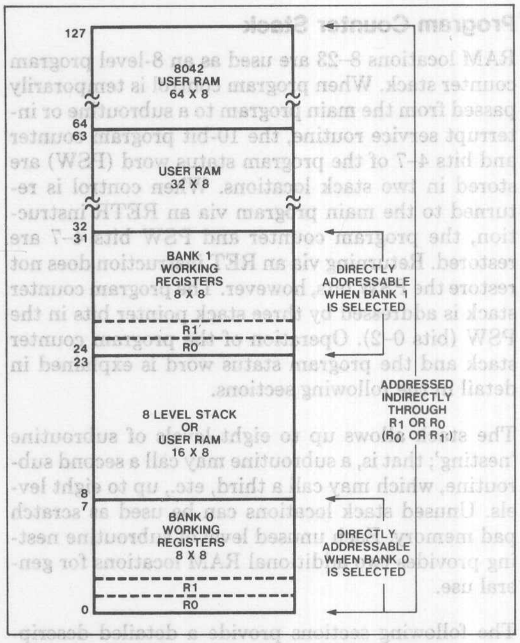


Figure 2-6. Data Memory Map

Working Registers

Dual banks of eight working registers are included in the UPI-41AH, 42 data memory. Locations 0–7 make up register bank 0 and locations 24–31 form register bank 1. A $\overline{\text{RESET}}$ signal automatically selects register bank 0. When bank 0 is selected, references to R_0–R_7 in UPI-41AH, 42 instructions operate on locations 0–7 in data memory. A "select register bank" instruction is used to select between the banks during program execution. If the instruction SEL RB1 (Select Register Bank 1) is executed, then program references to R_0–R_7 will operate on locations 24–31. As stated previously, registers 0 and 1 in the active register bank are used as indirect address registers for all locations in data memory.

Register bank 1 is normally reserved for handling interrupt service routines, thereby preserving the contents of the main program registers. The SEL RB1 instruction can be issued at the beginning of an interrupt service routine. Then, upon return to the main program, an RETR (return & restore status) instruction will automatically restore the previously selected bank. During interrupt processing, registers in bank 0 can be accessed indirectly using R_0' and R_1'.

If register bank 1 is not used, registers 24–31 can still serve as additional scratch pad memory.

Program Counter Stack

RAM locations 8–23 are used as an 8-level program counter stack. When program control is temporarily passed from the main program to a subroutine or interrupt service routine, the 10-bit program counter and bits 4–7 of the program status word (PSW) are stored in two stack locations. When control is returned to the main program via an RETR instruction, the program counter and PSW bits 4–7 are restored. Returning via an RET instruction does not restore the PSW bits, however. The program counter stack is addressed by three stack pointer bits in the PSW (bits 0–2). Operation of the program counter stack and the program status word is explained in detail in the following sections.

The stack allows up to eight levels of subroutine 'nesting'; that is, a subroutine may call a second subroutine, which may call a third, etc., up to eight levels. Unused stack locations can be used as scratch pad memory. Each unused level of subroutine nesting provides two additional RAM locations for general use.

The following sections provide a detailed description of the Program Counter Stack and the Program Status Word.

PROGRAM COUNTER

The UPI-41AH, 42 microcomputer has a 10-bit program counter (PC) which can directly address any of the 1024 locations in program memory. The program counter always contains the address of the next instruction to be executed and is normally incremented sequentially for each instruction to be executed when each instruction fetches occurs.

When control is temporarily passed from the main program to a subroutine or an interrupt routine, however, the PC contents must be altered to point to the address of the desired routine. The stack is used to save the current PC contents so that, at the end of the routine, main program execution can continue. The program counter is initialized to zero by a $\overline{\text{RESET}}$ signal.

PROGRAM COUNTER STACK

The Program Counter Stack is composed of 16 locations in Data Memory as illustrated in Figure 2-7. These RAM locations (8 through 23) are used to store the 10-bit program counter and 4 bits of the program status word.

An interrupt or CALL to a subroutine causes the contents of the program counter to be stored in one of the 8 register pairs of the program counter stack.

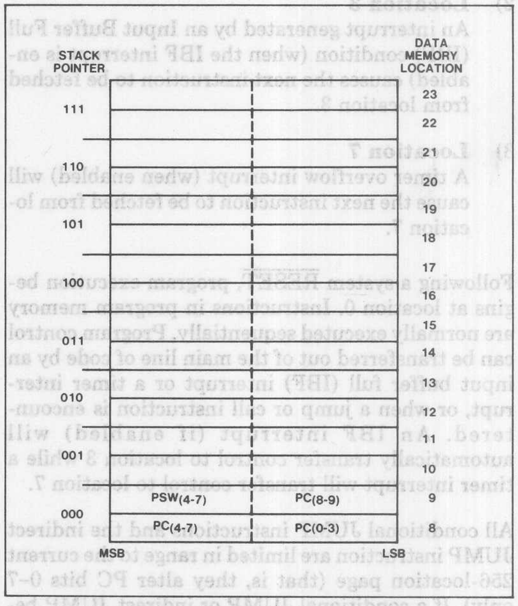


Figure 2-7. Program Counter Stack

A 3-bit Stack Pointer which is part of the Program Status Word (PSW) determines the stack pair to be used at a given time. The stack pointer is initialized by a $\overline{\text{RESET}}$ signal to 00H which corresponds to RAM locations 8 and 9.

The first call or interrupt results in the program counter and PSW contents being transferred to RAM locations 8 and 9 in the format shown in Figure 2-7. The stack pointer is automatically incremented by 1 to point to locations 10 and 11 in anticipation of another CALL.

Nesting of subroutines within subroutines can continue up to 8 levels without overflowing the stack. If overflow does occur the deepest address stored (locations 8 and 9) will be overwritten and lost since the stack pointer overflows from 07H to 00H. Likewise, the stack pointer will underflow from 00H to 07H.

The end of a subroutine is signaled by a return instruction, either RET or RETR. Each instruction will automatically decrement the Stack Pointer and transfer the contents of the proper RAM register pair to the Program Counter.

PROGRAM STATUS WORD

The 8-bit program status word illustrated in Figure 2-8 is used to store general information about program execution. In addition to the 3-bit Stack

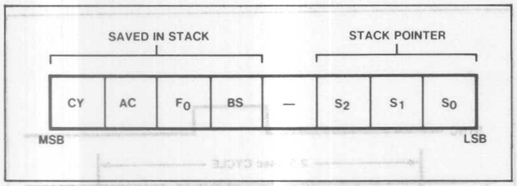


Figure 2-8. Program Status Word

Pointer discussed previously, the PSW includes the following flags:

- CY — Carry
- AC — Auxiliary Carry
- F_0 — Flag 0
- BS — Register Bank Select

The Program Status Word (PSW) is actually a collection of flip-flops located throughout the machine which are read or written as a whole. The PSW can be loaded to or from the accumulator by the MOV A, PSW or MOV PSW,A instructions. The ability to write directly to the PSW allows easy restoration of machine status after a power-down sequence.

The upper 4 bits of the PSW (bits 4, 5, 6, and 7) are stored in the PC Stack with every subroutine CALL or interrupt vector. Restoring the bits on a return is optional. The bits are restored if an RETR instruction is executed, but not if an RET is executed.

PSW bit definitions are as follows:

- Bits 0–2 Stack Pointer Bits S_0, S_1, S_2
- Bit 3 Not Used
- Bit 4 Working Register Bank
  0 = Bank 0
  1 = Bank 1
- Bit 5 Flag 0 bit (F_0)
  This is a general purpose flag which can be cleared or complemented and tested with conditional jump instructions. It may be used during data transfer to an external processor.
- Bit 6 Auxiliary Carry (AC)
  The flag status is determined by an ADD instruction and is used by the Decimal Adjustment instruction DAA.
- Bit 7 Carry (CY)
  The flag indicates that a previous operation resulted in overflow of the accumulator.

CONDITIONAL BRANCH LOGIC

Conditional Branch Logic in the UPI-41AH, 42 allows the status of various processor flags, inputs, and other hardware functions to directly affect program execution. The status is sampled in state 3 of the first cycle.

Table 2-2 lists the internal conditions which are testable and indicates the condition which will cause a jump. In all cases, the destination address must be within the page of program memory (256 locations) in which the jump instruction occurs.

OSCILLATOR AND TIMING CIRCUITS

The 8041A's internal timing generation is controlled by a self-contained oscillator and timing circuit. A choice of crystal, L-C or external clock can be used to derive the basic oscillator frequency.

The resident timing circuit consists of an oscillator, a state counter and a cycle counter as illustrated in Figure 2-9. Figure 2-10 shows instruction cycle timing.

Table 2-2. Conditional Branch Instructions

Device	Instruction Mnemonic		Jump Condition Jump if:
Accumulator	JZ	addr	All bits zero
	JNZ	addr	Any bit not zero
Accumulator bit	JBb	addr	Bit "b" = 1
Carry flag	JC	addr	Carry flag = 1
	JNC	addr	Carry flag = 0
User flag	JFO	addr	F_0 flag = 1
	JF1	addr	F_1 flag = 1
Timer flag	JTF	addr	Timer flag = 1
Test Input 0	JT0	addr	T_0 = 1
	JNT0	addr	T_0 = 0
Test Input 1	JT1	addr	T_1 = 1
	JNT1	addr	T_1 = 0
Input Buffer flag	JNIBF	addr	IBF flag = 0
Output Buffer flag	JOBF	addr	OBF flag = 1

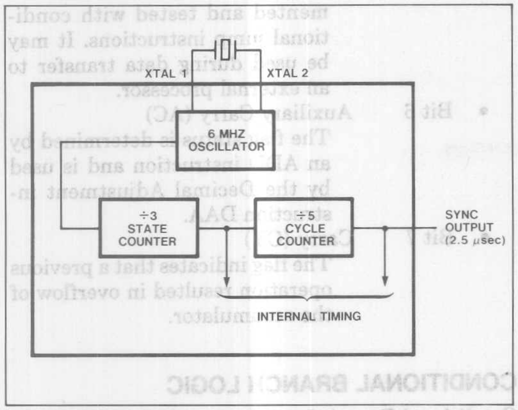


Figure 2-9. Oscillator Configuration

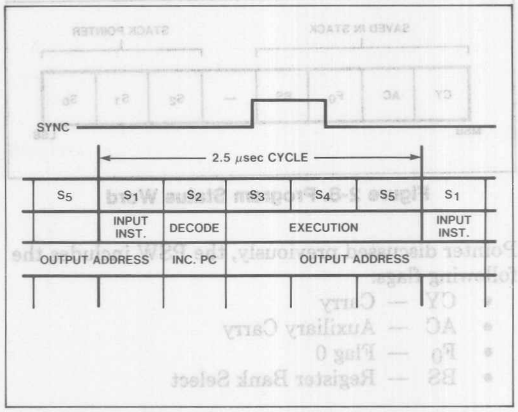


Figure 2-10. Instruction Cycle Timing

Oscillator

The on-board oscillator is a series resonant circuit with a frequency range of 1 to 12 (8041AH-2/8042/8742) MHz. Pins XTAL 1 and XTAL 2 are input and output (respectively) of a high gain amplifier stage. A crystal or inductor and capacitor connected between XTAL 1 and XTAL 2 provide the feedback and proper phase shift for oscillation. Recommended connections for crystal or L-C are shown in Figure 2-11.

State Counter

The output of the oscillator is divided by 3 in the state counter to generate a signal which defines the state times of the machine.

Each instruction cycle consists of five states as illustrated in Figure 2-10 and Table 2-3. The overlap of address and execution operations illustrated in Figure 2-10 allows fast instruction execution.

Table 2-3. Instruction Timing Diagram

INSTRUCTION	CYCLE 1					CYCLE 2				
	S1	S2	S3	S4	S5	S1	S2	S3	S4	S5
IN A,Pp	Fetch Instruction	Increment Program Counter	—	Increment Timer	—	—	Read Port	—	—	—
OUTL Pp,A	Fetch Instruction	Increment Program Counter	—	Increment Timer	Output To Port	—	—	—	—	—
ANL Pp, DATA	Fetch Instruction	Increment Program Counter	—	Increment Timer	Read Port	Fetch Immediate Data	—	Increment Program Counter	Output To Port	—
ORL Pp, DATA	Fetch Instruction	Increment Program Counter	—	Increment Timer	Read Port	Fetch Immediate Data	—	Increment Program Counter	Output To Port	—
MOVD A,Pp	Fetch Instruction	Increment Program Counter	Output Opcode/Address	Increment Timer	—	—	Read P2 Lower	—	—	—
MOVD Pp,A	Fetch Instruction	Increment Program Counter	Output Opcode/Address	Increment Timer	Output Data To P2 Lower	—	—	—	—	—
ANLD Pp,A	Fetch Instruction	Increment Program Counter	Output Opcode/Address	Increment Timer	Output Data	—	—	—	—	—
ORLD Pp,A	Fetch Instruction	Increment Program Counter	Output Opcode/Address	Increment Timer	Output Data	—	—	—	—	—
J (Conditional)	Fetch Instruction	Increment Program Counter	Sample Condition	Increment Timer	—	Fetch Immediate Data	—	Update Program Counter	—	—
MOV STS, A	Fetch Instruction	Increment Program Counter	—	Increment Timer	Update Status Register					
IN A,DBB	Fetch Instruction	Increment Program Counter	—	Increment Timer	—					
OUT DBB,A	Fetch Instruction	Increment Program Counter	—	Increment Timer	Output To Port					
STRT T STRT CNT	Fetch Instruction	Increment Program Counter	—	—	Start Counter					
STOP TCNT	Fetch Instruction	Increment Program Counter	—	—	Stop Counter					
EN I	Fetch Instruction	Increment Program Counter	—	Enable Interrupt	—					
DIS I	Fetch Instruction	Increment Program Counter	—	Disable Interrupt	—					
EN DMA	Fetch Instruction	Increment Program Counter	—	DMA Enabled DRQ Cleared	—					
EN FLAGS	Fetch Instruction	Increment Program Counter	—	OBF, $\overline{IBF}$ Output Enabled	—					

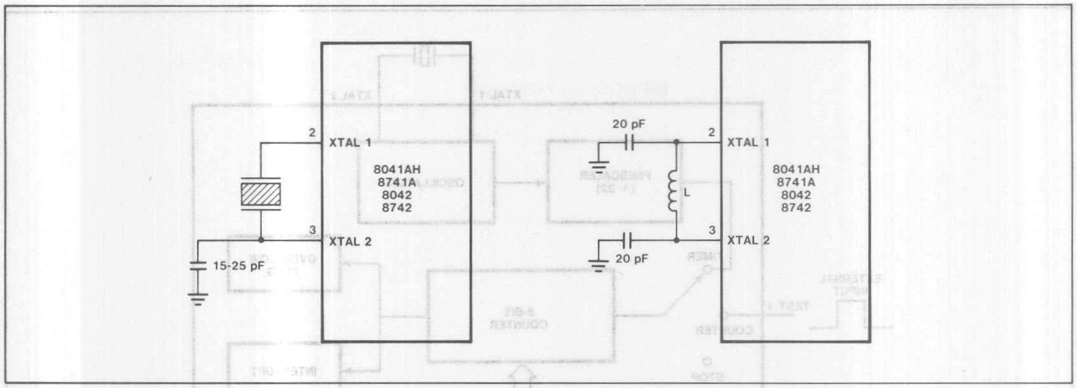


Figure 2-11. Recommended Crystal and L-C Connections

Cycle Counter

The output of the state counter is divided by 5 in the cycle counter to generate a signal which defines a machine cycle. This signal is call SYNC and is available continously on the SYNC output pin. It can be used to synchronize external circuitry or as a general purpose clock output. It is also used for synchronizing single-step.

Frequency Reference

The external crystal provides high speed and accurate timing generation. A crystal frequency of 5.9904 MHz is useful for generation of standard communication frequencies by the 8041AH/8741, 8042/8742. However, if an accurate frequency reference and maximum processor speed are not required, an inductor and capacitor may be used in place of the crystal as shown in Figure 2-11.

A recommended range of inductance and capacitance combinations is given below:

- L = 130 μH corresponds to 3 MHz
- L = 45 μH corresponds to 5 MHz

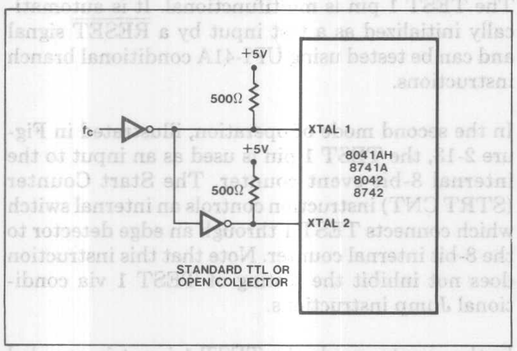


Figure 2-12. Recommended Connection For External Clock Signal

An external clock signal can also be used as a frequency reference to the 8741AH, 8741A, 8742 or 8042; however, the levels are *not* TTL compatible. The signal must be in the 1–12 MHz frequency range and must be connected to pins XTAL 1 and XTAL 2 by buffers with a suitable pull-up resistor to guarantee that a logic "1" is above 3.8 volts. The recommended connection is shown in Figure 2-12.

INTERVAL TIMER/EVENT COUNTER

The 8041AH, 8042 has a resident 8-bit timer/counter which has several software selectable modes of operation. As an interval timer, it can generate accurate delays from 80 microseconds to 20.48 milliseconds without placing undue burden on the processor. In the counter mode, external events such as switch closures or tachometer pulses can be counted and used to direct program flow.

Timer Configuration

Figure 2-13 illustrates the basic timer/counter configuration. An 8-bit register is used to count pulses from either the internal clock and prescaler or from an external source. The counter is presettable and readable with two MOV instructions which transfer the contents of the accumulator to the counter and vice-versa (i.e. MOV T, A and MOV A, T). The counter is stopped by a $\overline{\text{RESET}}$ or STOP TCNT instruction and remains stopped until restarted either as a timer (START T instruction) or as a counter (START CNT instruction). Once started, the counter will increment to its maximum count (FFH) and overflow to zero continuing its count until stopped by a STOP TCNT instruction or $\overline{\text{RESET}}$.

The increment from maximum count to zero (overflow) results in setting the Timer Flag (TF) and generating an interrupt request. The state of the overflow flag is testable with the conditional jump

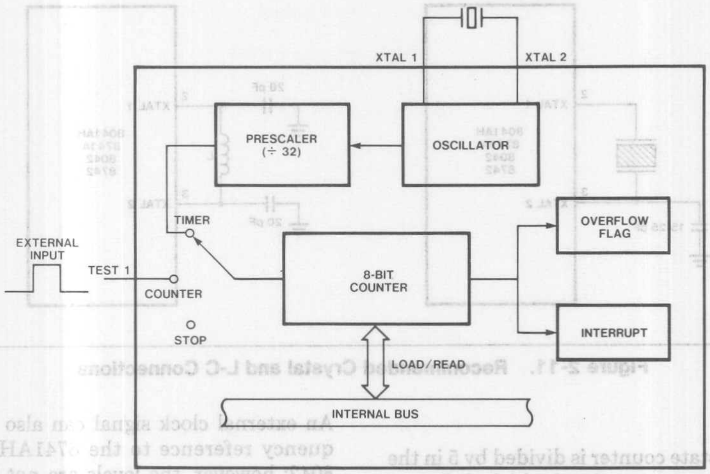


Figure 2-13. Timer Counter

instruction, JTF. The flag is reset by executing a JTF or by a $\overline{\text{RESET}}$ signal.

The timer interrupt request is stored in a latch and ORed with the input buffer full interrupt request. The timer interrupt can be enabled or disabled independent of the IBF interrupt by the EN TCNTI and DIS TCTNI instructions. If enabled, the counter overflow will cause a subroutine call to location 7 where the timer service routine is stored. If the timer and Input Buffer Full interrupts occur simultaneously, the IBF source will be recognized and the call will be to location 3. Since the timer interrupt is latched, it will remain pending until the DBBIN register has been serviced and will immediately be recognized upon return from the service routine. A pending timer interrupt is reset by the initiation of a timer interrupt service routine.

Event Counter Mode

The STRT CNT instruction connects the TEST 1 input pin to the counter input and enables the counter. Note this instruction does not clear the counter. The counter is incremented on high to low transitions of the TEST 1 input. The TEST 1 input must remain high for a minimum of one state in order to be registered (250 ns at 12 MHz). The maximum count frequency is one count per three instruction cycles (267 kHz at 12 MHz). There is no minimum frequency limit.

Timer Mode

The STRT T instruction connects the internal clock to the counter input and enables the counter. The input clock is derived from the SYNC signal of the internal oscillator and the divide-by-32 prescaler. The configuration is illustrated in Figure 2-13. Note this instruction does not clear the timer register. Various delays and timing sequences between 40 μsec and 10.24 msec can easily be generated with a minimum of software timing loops (at 12 MHz).

Times longer than 10.24 msec can be accurately measured by accumulating multiple overflows in a register under software control. For time resolution less than 40 μsec, an external clock can be applied to the TEST 1 counter input (see Event Counter Mode). The minimum time resolution with an external clock is 3.75 μsec (267 kHz at 12 MHz).

TEST 1 Event Counter Input

The TEST 1 pin is multifunctional. It is automatically initialized as a test input by a $\overline{\text{RESET}}$ signal and can be tested using UPI-41A conditional branch instructions.

In the second mode of operation, illustrated in Figure 2-13, the TEST 1 pin is used as an input to the internal 8-bit event counter. The Start Counter (STRT CNT) instruction controls an internal switch which connects TEST 1 through an edge detector to the 8-bit internal counter. Note that this instruction does not inhibit the testing of TEST 1 via conditional Jump instructions.

In the counter mode the TEST 1 input is sampled once per instruction cycle. After a high level is detected, the next occurence of a low level at TEST 1

will cause the counter to increment by one.

The event counter functions can be stopped by the Stop Timer/Counter (STOP TCNT) instruction. When this instruction is executed the TEST 1 pin becomes a test input and functions as previously described.

TEST INPUTS

There are two multifunction pins designated as Test Inputs, TEST 0 and TEST 1. In the normal mode of operation, status of each of these lines can be directly tested using the following conditional Jump instructions:

- JT0 Jump if TEST 0 = 1
- JNT0 Jump if TEST 0 = 0
- JT1 Jump if TEST 1 = 1
- JNT1 Jump if TEST 1 = 0

The test inputs are TTL compatible. An external logic signal connected to one of the test inputs will be sampled at the time the appropriate conditional jump instruction is executed. The path of program execution will be altered depending on the state of the external signal when sampled.

INTERRUPTS

The 8041AH/8741A, 8042/8742 has the following internal interrupts:

- Input Buffer Full (IBF) interrupt
- Timer Overflow interrupt

The IBF interrupt forces a CALL to location 3 in program memory; a timer-overflow interrupt forces a CALL to location 7. The IBF interrupt is enabled by the EN I instruction and disabled by the DIS I instruction. The timer-overflow interrupt is enabled and disabled by the EN TNCTI and DIS TCNTI instructions, respectively.

Figure 2-14 illustrates the internal interrupt logic. An IBF interrupt request is generated whenever $\overline{WR}$ and $\overline{CS}$ are both low, regardless of whether interrupts are enabled. The interrupt request is cleared upon entering the IBF service routine only. That is, the DIS I instruction does not clear a pending IBF interrupt.

Interrupt Timing Latency

When the IBF interrupt is enabled and an IBF interrupt request occurs, an interrupt sequence is initiated as soon as the currently executing instruction is completed. The following sequence occurs:

- A CALL to location 3 is forced.
- The program counter and bits 4–7 of the Program Status Word are stored in the stack.
- The stack pointer is incremented.

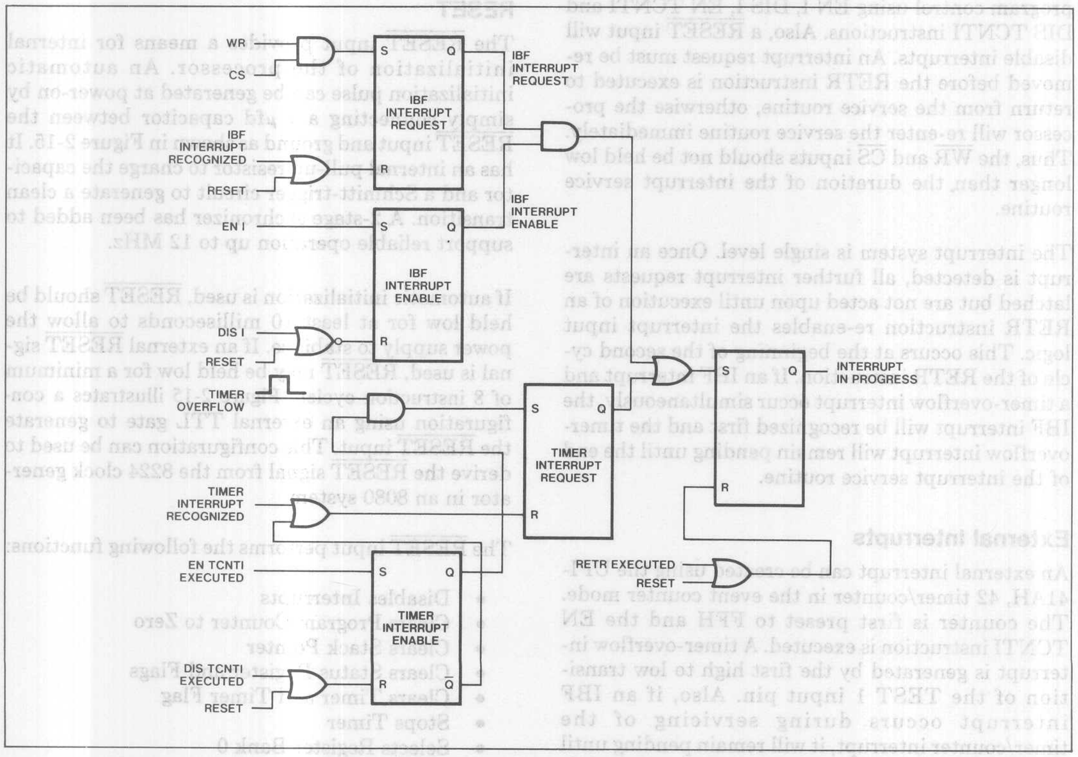


Figure 2-14. Interrupt Logic

Location 3 in program memory should contain an unconditional jump to the beginning of the IBF interrupt service routine elsewhere in program memory. At the end of the service routine, an RETR (Return and Restore Status) instruction is used to return control to the main program. This instruction will restore the program counter and PSW bits 4–7, providing automatic restoration of the previously active register bank as well. RETR also re-enables interrupts.

A timer-overflow interrupt is enabled by the EN TCNTI instruction and disabled by the DIS TCNTI instruction. If enabled, this interrupt occurs when the timer/counter register overflows. A CALL to location 7 is forced and the interrupt routine proceeds as described above.

The interrupt service latency is the sum of current instruction time, interrupt recognition time, and the internal call to the interrupt vector address. The worst case latency time for servicing an interrupt is 7 clock cycles. Best case latency is 4 clock cycles.

Interrupt Timing

Interrupt inputs may be enabled or disabled under program control using EN I, DIS I, EN TCNTI and DIS TCNTI instructions. Also, a $\overline{\text{RESET}}$ input will disable interrupts. An interrupt request must be removed before the RETR instruction is executed to return from the service routine, otherwise the processor will re-enter the service routine immediately. Thus, the $\overline{\text{WR}}$ and $\overline{\text{CS}}$ inputs should not be held low longer than the duration of the interrupt service routine.

The interrupt system is single level. Once an interrupt is detected, all further interrupt requests are latched but are not acted upon until execution of an RETR instruction re-enables the interrupt input logic. This occurs at the beginning of the second cycle of the RETR instruction. If an IBF interrupt and a timer-overflow interrupt occur simultaneously, the IBF interrupt will be recognized first and the timer-overflow interrupt will remain pending until the end of the interrupt service routine.

External Interrupts

An external interrupt can be created using the UPI-41AH, 42 timer/counter in the event counter mode. The counter is first preset to FFH and the EN TCNTI instruction is executed. A timer-overflow interrupt is generated by the first high to low transition of the TEST 1 input pin. Also, if an IBF interrupt occurs during servicing of the timer/counter interrupt, it will remain pending until the end of the service routine.

Host Interrupts And DMA

If needed, two external interrupts to the host system can be created using the EN FLAGS instruction. This instruction allocates two I/O lines on PORT 2 (P_{24} and P_{25}). P_{24} is the Output Buffer Full interrupt request line to the host system; P_{25} is the Input Buffer empty interrupt request line. These interrupt outputs reflect the internal status of the OBF flag and the IBF inverted flag. Note, these outputs may be inhibited by writing a "0" to these pins. Reenabling interrupts is done by writing a "1" to these port pins. Interrupts are typically enabled after power on since the I/O ports are set in a "1" condition. The EN FLAG's effect is only cancelled by a device RESET.

DMA handshaking controls are available from two pins on PORT 2 of the UPI-41A microcomputer. These lines (P_{26} and P_{27}) are enabled by the EN DMA instruction. P_{26} becomes DMA request (DRQ) and P_{27} becomes DMA acknowledge ($\overline{\text{DACK}}$). The UPI program initiates a DMA request by writing a "1" to P_{26}. The DMA controller transfers the data into the DBBIN data register using DACK which acts as a chip select. The EN DMA instruction can only be cancelled by a chip RESET.

RESET

The $\overline{\text{RESET}}$ input provides a means for internal initialization of the processor. An automatic initialization pulse can be generated at power-on by simply connecting a 1 μfd capacitor between the $\overline{\text{RESET}}$ input and ground as shown in Figure 2-15. It has an internal pull-up resistor to charge the capacitor and a Schmitt-trigger circuit to generate a clean transition. A 2-stage sychronizer has been added to support reliable operation up to 12 MHz.

If automatic initialization is used, $\overline{\text{RESET}}$ should be held low for at least 10 milliseconds to allow the power supply to stabilize. If an external $\overline{\text{RESET}}$ signal is used, $\overline{\text{RESET}}$ may be held low for a minimum of 8 instruction cycles. Figure 2-15 illustrates a configuration using an external TTL gate to generate the $\overline{\text{RESET}}$ input. This configuration can be used to derive the $\overline{\text{RESET}}$ signal from the 8224 clock generator in an 8080 system.

The $\overline{\text{RESET}}$ input performs the following functions:

- Disables Interrupts
- Clears Program Counter to Zero
- Clears Stack Pointer
- Clears Status Register and Flags
- Clears Timer and Timer Flag
- Stops Timer
- Selects Register Bank 0
- Sets PORTS 1 and 2 to Input Mode

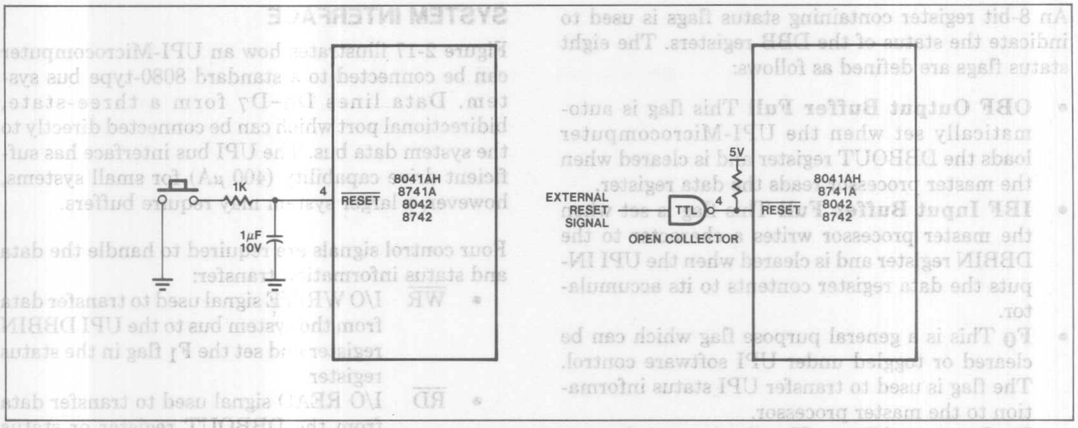


Figure 2-15. External Reset Configuration

DATA BUS BUFFER

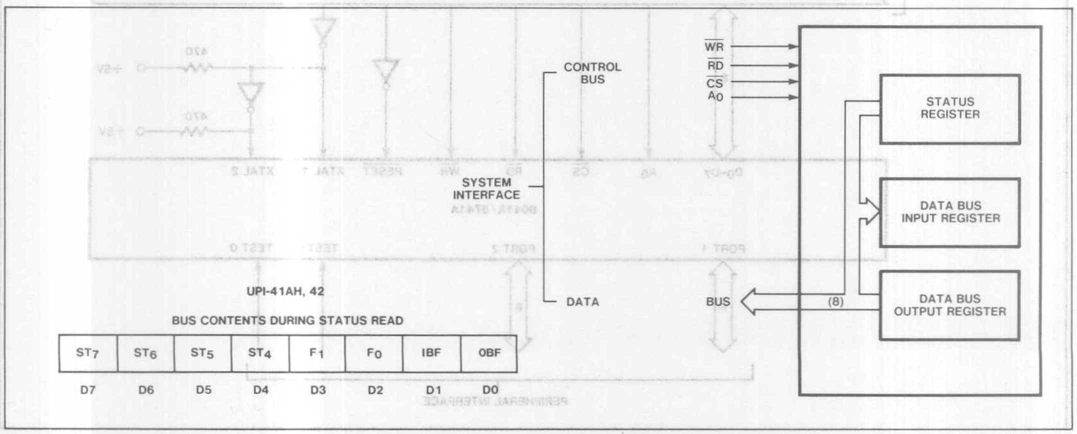
Two 8-bit data bus buffer registers, DBBIN and DBBOUT, serve as temporary buffers for commands and data flowing between it and the master processor. Externally, data is transmitted or received by the DBB registers upon execution of an INput or OUTput instruction by the master processor. Four control signals are used:

- A_0 Address input signifying control or data
- $\overline{CS}$ Chip Select
- $\overline{RD}$ Read strobe
- $\overline{WR}$ Write strobe

Transfer can be implemented with or without UPI program interference by enabling or disabling an internal UPI interrupt. Internally, data transfer between the DBB and the UPI accumulator is under software control and is completely asynchronous to the external processor timing. This allows the UPI software to handle peripheral control tasks independent of the main processor while still maintaining a data interface with the master system.

Configuration

Figure 2-16 illustrates the internal configuration of the DBB registers. Data is stored in two 8-bit buffer registers, DBBIN and DBBOUT. DBBIN and DBBOUT may be accessed by the external processor using the $\overline{WR}$ line and the $\overline{RD}$ line, respectively. The data bus is a bidirectional, three-state bus which can be connected directly to an 8-bit microprocessor system. Four control lines ($\overline{WR}$, $\overline{RD}$, $\overline{CS}$, A_0) are used by the external processor to transfer data to and from the DBBIN and DBBOUT registers.



2-16. Data Bus Buffer Configuration

An 8-bit register containing status flags is used to indicate the status of the DBB registers. The eight status flags are defined as follows:

- **OBF Output Buffer Full** This flag is automatically set when the UPI-Microcomputer loads the DBBOUT register and is cleared when the master processor reads the data register.
- **IBF Input Buffer Full** This flag is set when the master processor writes a character to the DBBIN register and is cleared when the UPI INputs the data register contents to its accumulator.
- **F_0** This is a general purpose flag which can be cleared or toggled under UPI software control. The flag is used to transfer UPI status information to the master processor.
- **F_1 Command/Data** This flag is set to the condition of the A_0 input line when the master processor writes a character to the data register. The F_1 flag can also be cleared or toggled under UPI-Microcomputer program control.
- **ST4 Through ST7** These bits are user defined status bits. They are defined by the MOV STS,A instruction.

All flags in the status register are automatically cleared by a $\overline{\text{RESET}}$ input.

SYSTEM INTERFACE

Figure 2-17 illustrates how an UPI-Microcomputer can be connected to a standard 8080-type bus system. Data lines D_0–D_7 form a three-state, bidirectional port which can be connected directly to the system data bus. The UPI bus interface has sufficient drive capability (400 μA) for small systems, however, a larger system may require buffers.

Four control signals are required to handle the data and status information transfer:

- $\overline{\text{WR}}$ I/O WRITE signal used to transfer data from the system bus to the UPI DBBIN register and set the F_1 flag in the status register.
- $\overline{\text{RD}}$ I/O READ signal used to transfer data from the DBBOUT register or status register to the system data bus.
- $\overline{\text{CS}}$ CHIP SELECT signal used to enable one 8041A out of several connected to a common bus.
- A_0 Address input used to select either the 8-bit status register or DBBOUT register during an I/O READ. Also, the signal is used to set the F_1 flag in the status register during an I/O WRITE.

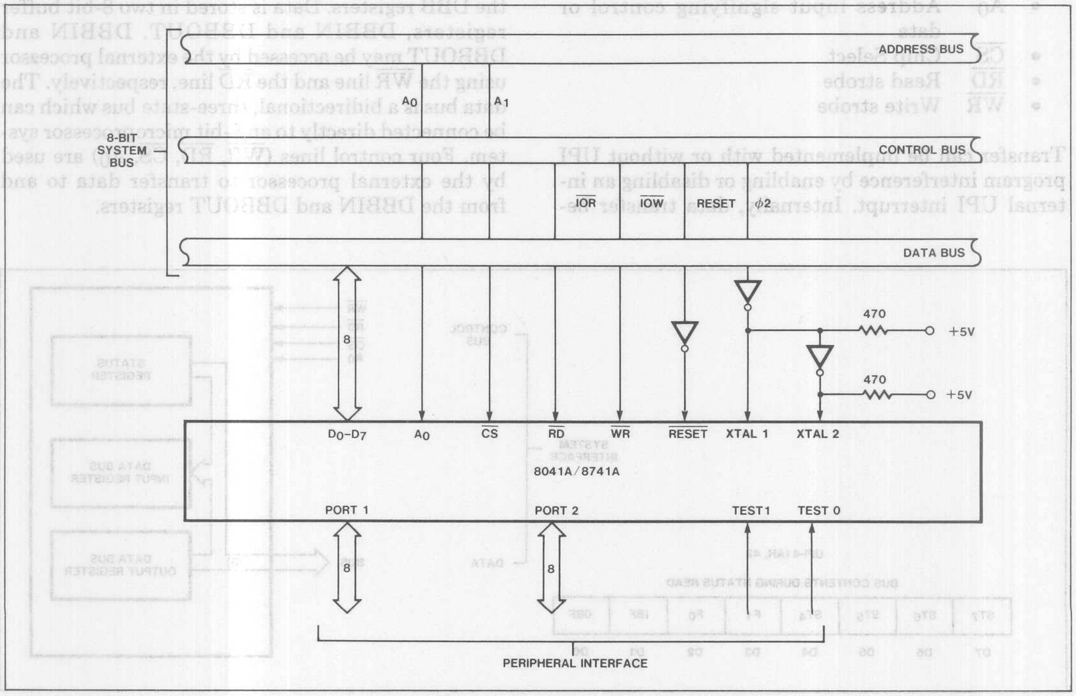


Figure 2-17. Interface to 8080 System Bus

The $\overline{WR}$ and $\overline{RD}$ signals are active low and are standard MCS-80 peripheral control signals used to synchronize data transfer between the system bus and peripheral devices.

The $\overline{CS}$ and A_0 signals are decoded from the address bus of the master system. In a system with few I/O devices a linear addressing configuration can be used where A_0 and A_1 lines are connected directly to A_0 and $\overline{CS}$ inputs (see Figure 2-17).

Data Read

Table 2-4 illustrates the relative timing of a DBBOUT Read. When $\overline{CS}$, A_0, and $\overline{RD}$ are low, the contents of the DBBOUT register is placed on the three-state Data lines D_0–D_7 and the OBF flag is cleared.

The master processor uses $\overline{CS}$, A_0, $\overline{WR}$, and $\overline{RD}$ to control data transfer between the DBBOUT register and the master system. The following operations are under master processor control:

Table 2-4. Data Transfer Controls

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A_0	
0	0	1	0	Read DBBOUT register
0	0	1	1	Read STATUS register
0	1	0	0	Write DBBIN data register
0	1	0	1	Write DBBIN command register
1	x	x	x	Disable DBB

Status Read

Table 2-4 shows the logic sequence required for a STATUS register read. When $\overline{CS}$ and $\overline{RD}$ are low with A_0 high, the contents of the 8-bit status register appears on Data lines D_0–D_7.

Data Write

Table 2-4 shows the sequence for writing information to the DBBIN register. When $\overline{CS}$ and $\overline{WR}$ are low, the contents of the system data bus is latched into DBBIN. Also, the IBF flag is set and an interrupt is generated, if enabled.

Command Write

During any write (Table 2-4), the state of the A_0 input is latched into the status register in the F_1 (command/data) flag location. This additional bit is used to signal whether DBBIN contents are command ($A_0 = 1$) or data ($A_0 = 0$) information.

INPUT/OUTPUT INTERFACE

The UPI-41A has 16 lines for input and output functions. These I/O lines are grouped as two 8-bit TTL compatible ports: PORTS 1 and 2. The port lines can individually function as either inputs or outputs under software control. In addition, the lower 4 lines of PORT 2 can be used to interface to an 8243 I/O expander device to increase I/O capacity to 28 or more lines. The additional lines are grouped as 4-bit ports: PORTS 4, 5, 6, and 7.

PORTS 1 and 2

PORTS 1 and 2 are each 8 bits wide and have the same I/O characteristics. Data written to these ports by an OUTL Pp,A instruction is latched and remains unchanged until it is rewritten. Input data is sampled at the time the IN, A,Pp instruction is executed. Therefore, input data must be present at the PORT until read by an INput instruction. PORT 1 and 2 inputs are fully TTL compatible and outputs will drive one standard TTL load.

Circuit Configuration

The PORT 1 and 2 lines have a special output structure (shown in Figure 2-18) that allows each line to serve as an input, an output, or both, even though outputs are statically latched.

Each line has a permanent high impedance pull-up (50KΩ) which is sufficient to provide source current for a TTL high level, yet can be pulled low by a standard TTL gate drive. Whenever a "1" is written to a line, a low impedance pull-up (5K) is switched in momentarily (500 ns) to provide a fast transition from 0 to 1. When a "0" is written to the line, a low impedance pull-down (300Ω) is active to provide TTL current sinking capability.

To use a particular PORT pin as an input, a logic "1" must first be written to that pin.

NOTE: A $\overline{RESET}$ intializes all PORT pins to the high impedance logic "1" state.

An external TTL device connected to the pin has sufficient current sinking capability to pull-down the pin to the low state. An IN A,Pp instruction will sample the status of PORT pin and will input the proper logic level. With no external input connected, the IN A,Pp instruction inputs the previous output status.

This structure allows input and output information on the same pin and also allows any mix of input and output lines on the same port. However, when inputs and outputs are mixed on one PORT, a PORT write will cause the strong internal pull-ups to turn on at all inputs. If a switch or other low impedance device is connected to an input, a PORT write ("1" to an input) could cause current limits on internal lines to

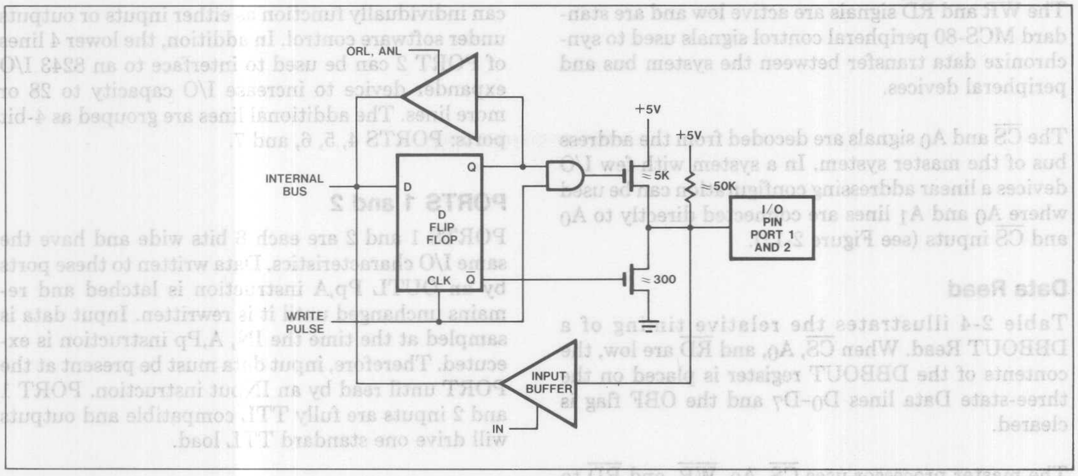


Figure 2-18. Quasi-Bidirectional Port Structure

be exceeded. Figure 2-19 illustrates the recommended connection when inputs and outputs are mixed on one PORT.

The bidirectional port structure in combination with the UPI-41AH, 42 logical AND and OR instructions provides an efficient means for handling single line inputs and outputs within an 8-bit processor.

PORTS 4, 5, 6, and 7

By using an 8243 I/O expander, 16 additional I/O lines can be connected to the UPI-41AH, 42 and directly addressed as 4-bit I/O ports using UPI-41AH, 42 instructions. This feature saves program space and design time, and improves the bit handling capability of the UPI-41AH, 42.

The lower half of PORT 2 provides an interface to the 8243 as illustrated in Figure 2-20. The PROG pin is used as a strobe to clock address and data information via the PORT 2 interface. The extra 16 I/O lines are referred to in UPI software as PORTS 4, 5, 6, and 7. Each PORT can be directly addressed and can be ANDed and ORed with an immediate data mask. Data can be moved directly to the accumulator from the expander PORTS (or vice-versa).

The 8243 I/O ports, PORTS 4, 5, 6, and 7, provide more drive capability than the UPI-41AH, 42 bidirectional ports. The 8243 output is capable of driving about 5 standard TTL loads.

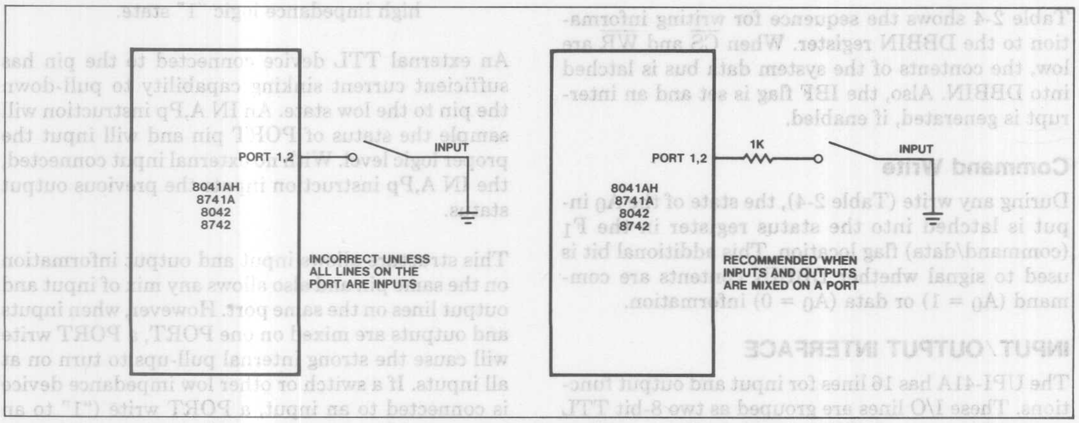


Figure 2-19. Recommended PORT Input Connections

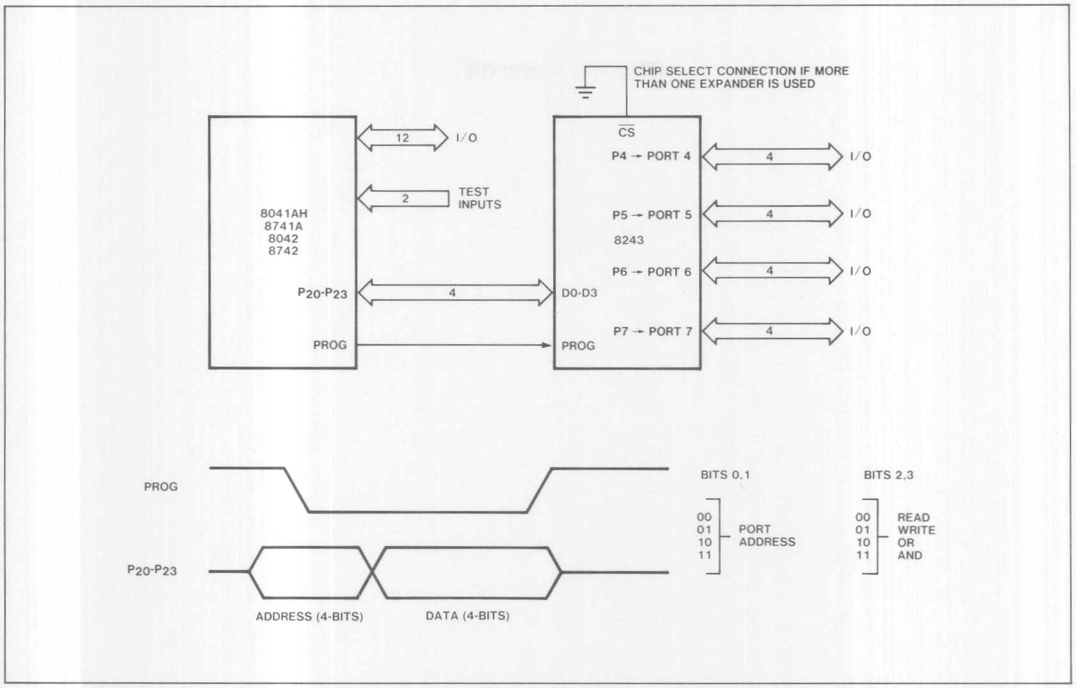


Figure 2-20. 8243 Expander Interface

Multiple 8243's can be connected to the PORT 2 interface. In normal operation, only one of the 8243's would be active at the time an Input or Output command is executed. The upper half of PORT 2 is used to provide chip select signals to the 8243's. Figure 2-21 shows how four 8243's could be connected. Software is needed to select and set the proper PORT 2 pin before an INPUT or OUTPUT command to PORTS 4–7 is executed. In general, the software overhead required is very minor compared to the added flexibility of having a large number of I/O pins available.

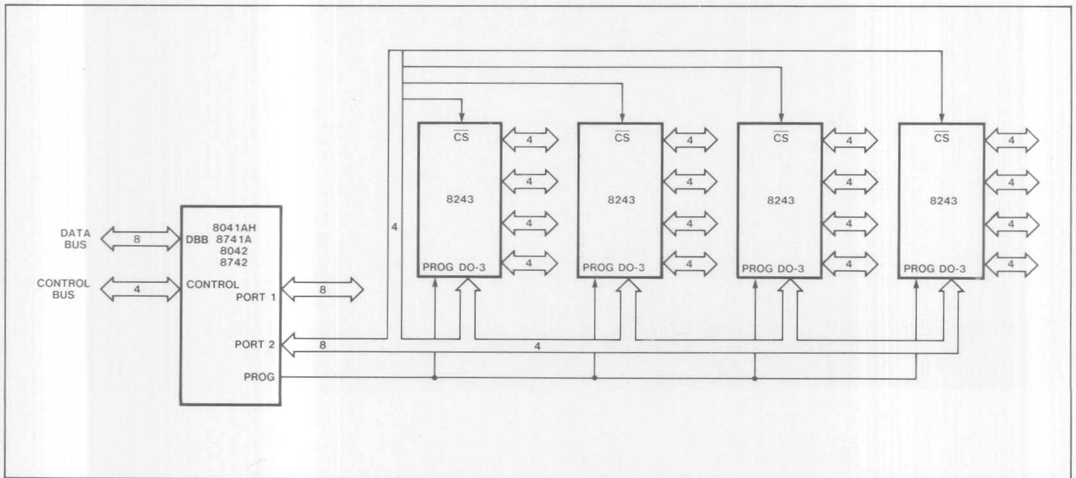


Figure 2-21. Multiple 8243 Expansion

Instruction Set 3

CHAPTER 3
INSTRUCTION SET

The UPI-41AH, 42 Instruction Set is opcode-compatible with the MCS-48 set except for the elimination of external program and data memory instructions and the addition of the data bus buffer instructions. It is very straightforward and efficient in its use of program memory. All instructions are either 1 or 2 bytes in length (over 70% are only 1 byte long) and over half of the instructions execute in one machine cycle. The remainder require only two cycles and include Branch, Immediate, and I/O operations.

The UPI-41AH, 42 Instruction Set efficiently handles the single-bit operations required in control applications. Special instructions allow port bits to be set or cleared individually. Also, any accumulator bit can be directly tested via conditional branch instructions. Additional instructions are included to simplify loop counters, table look-up routines and N-way branch routines.

The UPI-41AH, 42 Microcomputer handles arithmetic operations in both binary and BCD for efficient interface to peripherals such as keyboards and displays.

The instruction set can be divided into the following groups:

- Data Moves
- Accumulator Operations
- Flags
- Register Operations
- Branch Instructions
- Control
- Timer Operations
- Subroutines
- Input/Output Instructions

Data Moves (See Instruction Summary)

The 8-bit accumulator is the control point for all data transfers within the UPI-41AH, 42. Data can be transferred between the 8 registers of each working register bank and the accumulator directly (i.e., with a source or destination register specified by 3 bits in the instruction). The remaining locations in the RAM array are addressed either by R_0 or R_1 of the active register bank. Transfers to and from RAM require one cycle.

Constants stored in Program Memory can be loaded directly into the accumulator or the eight working registers. Data can also be transferred directly between the accumulator and the on-board timer/counter, the Status Register (STS), or the Program Status Word (PSW). Transfers to the STS register alter bits 4-7 only. Transfers to the PSW alter machine status accordingly and provide a means of restoring status after an interrupt or of altering the stack pointer if necessary.

Accumulator Operations

Immediate data, data memory, or the working registers can be added (with or without carry) to the accumulator. These sources can also be ANDed, ORed, or exclusive ORed to the accumulator. Data may be moved to or from the accumulator and working registers or data memory. The two values can also be exchanged in a single operation.

The lower 4 bits of the accumulator can be exchanged with the lower 4 bits of any of the internal RAM locations. This operation, along with an instruction which swaps the upper and lower 4-bit halves of the accumulator, provides easy handling of BCD numbers and other 4-bit quantities. To facilitate BCD arithmetic a Decimal Adjust instruction is also included. This instruction is used to correct the result of the binary addition of two 2-digit BCD numbers. Performing a decimal adjust on the result in the accumulator produces the desired BCD result.

The accumulator can be incremented, decremented, cleared, or complemented and can be rotated left or right 1 bit at a time with or without carry.

A subtract operation can be easily implemented in UPI-41AH, 42 software using three single-byte, single-cycle instructions. A value can be subtracted from the accumulator by using the following instructions:

- Complement the accumulator
- Add the value to the accumulator
- Complement the accumulator

Flags

There are four user accessible flags:

- Carry
- Auxiliary Carry
- F_0
- F_1

The Carry flag indicates overflow of the accumulator, while the Auxiliary Carry flag indicates overflow between BCD digits and is used during decimal adjust operations. Both Carry and Auxiliary Carry are part of the Program Status Word (PSW) and are stored in the stack during subroutine calls. The F_0 and F_1 flags are general-purpose flags which can be cleared or complemented by UPI instructions. F_0 is accessible via the Program Status Word and is stored in the stack with the Carry flags. F_1 reflects the condition of the A_0 line, and caution must be used when setting or clearing it.

Register Operations

The working registers can be accessed via the accumulator as explained above, or they can be loaded with immediate data constants from program memory. In addition, they can be incremented or decremented directly, or they can be used as loop counters as explained in the section on branch instructions.

Additional Data Memory locations can be accessed with indirect instructions via R_0 and R_1.

Branch Instructions

The UPI-41AH, 42 Instruction Set includes 17 jump instructions. The unconditional jump instruction allows jumps anywhere in the 1K words of program memory. All other jump instructions are limited to the current page (256 words) of program memory.

Conditional jump instructions can test the following inputs and machine flags:

- TEST 0 input pin
- TEST 1 input pin
- Input Buffer Full flag
- Output Buffer Full flag
- Timer flag
- Accumulator zero
- Accumulator bit
- Carry flag
- F_0 flag
- F_1 flag

The conditions tested by these instructions are the instantaneous values at the time the conditional jump instruction is executed. For instance, the jump on accumulator zero instruction tests the accumulator itself, not an intermediate flag.

The decrement register and jump if not zero (DJNZ) instruction combines decrement and branch operations in a single instruction which is useful in implementing a loop counter. This instruction can designate any of the 8 working registers as a counter and can effect a branch to any address within the current page of execution.

A special indirect jump instruction (JMPP @A) allows the program to be vectored to any one of several different locations based on the contents of the accumulator. The contents of the accumulator point to a location in program memory which contains the jump address. As an example, this instruction could be used to vector to any one of several routines based on an ASCII character which has been loaded into the accumulator. In this way, ASCII inputs can be used to initiate various routines.

Control

The UPI-41AH, 42 Instruction Set has six instructions for control of the DMA, interrupts, and selection of working register banks.

The UPI-41AH, 42 provides two instructions for control of the external microcomputer system. IBF and OBF flags can be routed to PORT 2 allowing interrupts of the external processor. DMA handshaking signals can also be enabled using lines from PORT 2.

The IBF interrupt can be enabled and disabled using two instructions. Also, the interrupt is automatically disabled following a RESET input or during an interrupt service routine.

The working register bank switch instructions allow the programmer to immediately substitute a second 8 register bank for the one in use. This effectively provides either 16 working registers or the means for quickly saving the contents of the first 8 registers in response to an interrupt. The user has the option of switching register banks when an interrupt occurs. However, if the banks are switched, the original bank will automatically be restored upon execution of a return and restore status (RETR) instruction at the end of the interrupt service routine.

Timer

The 8-bit on-board timer/counter can be loaded or read via the accumulator while the counter is stopped or while counting.

The counter can be started as a timer with an internal clock source or as an event counter or timer with an external clock applied to the TEST 1 pin. The instruction executed determines which clock source is used. A single instruction stops the counter whether it is operating with an internal or an external clock source. In addition, two instructions allow the timer interrupt to be enabled or disabled.

Subroutines

Subroutines are entered by executing a call instruction. Calls can be made to any address in the 1K word program memory. Two separate return instructions determine whether or not status (i.e., the upper 4 bits of the PSW) is restored upon return from a subroutine.

Input/Output Instructions

Two 8-bit data bus buffer registers (DBBIN and DBBOUT) and an 8-bit status register (STS) enable the UPI-41A universal peripheral interface to communicate with the external microcomputer system. Data can be INputted from the DBBIN register to

the accumulator. Data can be OUTputted from the accumulator to the DBBOUT register.

The STS register contains four user-definable bits (ST_4–ST_7) plus four reserved status bits (IBF, OBF, F_0, and F_1). The user-definable bits are set from the accumulator.

The UPI-41AH, 42 peripheral interface has two 8-bit static I/O ports which can be loaded to and from the accumulator. Outputs are statically latched but inputs to the ports are sampled at the time an IN instruction is executed. In addition, immediate data from program memory can be ANDed and ORed directly to PORTS 1 and 2 with the result remaining on the port. This allows "masks" stored in program memory to be used to set or reset individual bits on the I/O ports. PORTS 1 and 2 are configured to allow input on a given pin by first writing a "1" to the pin.

Four additional 4-bit ports are available through the 8243 I/O expander device. The 8243 interfaces to the UPI-41AH, 42 peripheral interface via four PORT 2 lines which form an expander bus. The 8243 ports have their own AND and OR instructions like the on-board ports, as well as move instructions to transfer data in or out. The expander AND or OR instructions, however, combine the contents of the accumulator with the selected port rather than with immediate data as is done with the on-board ports.

INSTRUCTION SET DESCRIPTION

The following section provides a detailed description of each UPI instruction and illustrates how the instructions are used.

For further information about programming the UPI, consult the *8048/8041A Assembly Language Manual.*

Table 3-1. Symbols and Abbreviations Used

Symbol	Definition
A	Accumulator
C	Carry
DBBIN	Data Bus Buffer Input
DBBOUT	Data Bus Buffer Output
F_0, F_1	FLAG 0, FLAG 1 (C/D flag)
I	Interrupt
P	Mnemonic for "in-page" operation
PC	Program Counter
Pp	Port designator (p = 1, 2, or 4–7)
PSW	Program Status Word
Rr	Register designator (r = 0–7)
SP	Stack Pointer
STS	Status register
T	Timer
TF	Timer Flag
T_0, T_1	TEST 0, TEST 1
#	Immediate data prefix
@	Indirect address prefix
(( ))	Double parentheses show the effect of @, that is, @RO is shown as ((RO)).
( )	Contents of

Table 3-2. Instruction Set Summary

Mnemonic		Operation Description	Bytes	Cycles
Accumulator				
ADD	A,Rr	Add register to A	1	1
ADD	A,@Rr	Add data memory to A	1	1
ADD	A,#data	Add immediate to A	2	2
ADDC	A,Rr	Add register to A with carry	1	1
ADDC	A,@Rr	Add data memory to A with carry	1	1
ADDC	A,#data	Add immediate to A with carry	2	2
ANL	A,Rr	And register to A	1	1
ANL	A,@Rr	And data memory to A	1	1
ANL	A,#data	And immediate to A	2	2
ORL	A,Rr	Or register to A	1	1
ORL	A,@Rr	Or data memory to A	1	1
ORL	A,#data	Or immediate to A	2	2
XRL	A,Rr	Exclusive Or register to A	1	1
XRL	A,@Rr	Exclusive Or data memory to A	1	1
XRL	A,#data	Exclusive Or immediate to A	2	2
INC	A	Increment A	1	1
DEC	A	Decrement A	1	1
CLR	A	Clear A	1	1
CPL	A	Complement A	1	1
DA	A	Decimal Adjust A	1	1
SWAP	A	Swap nibbles of A	1	1
RL	A	Rotate A left	1	1
RLC	A	Rotate A left through carry	1	1
RR	A	Rotate A right	1	1
RRC	A	Rotate A right through carry	1	1

Table 3-2. Instruction Set Summary (Con't.)

Mnemonic		Operation Description	Bytes	Cycles
INPUT/OUTPUT				
IN	A,Pp	Input port to A	1	2
OUTL	Pp,A	Output A to port	1	2
ANL	Pp,#data	And immediate to port	2	2
ORL	Pp,#data	Or immediate to port	2	2
IN	A,DBB	Input DBB to A, clear IBF	1	1
OUT	DBB,A	Output A to DBB, Set OBF	1	1
MOV	STS,A	A_4–A_7 to bits 4–7 of status	1	1
MOVD	A,Pp	Input Expander port to A	1	2
MOVD	Pp,A	Output A to Expander port	1	2
ANLD	Pp,A	And A to Expander port	1	2
ORLD	Pp,A	Or A to Expander port	1	2
DATA MOVES				
MOV	A,Rr	Move register to A	1	1
MOV	A,@Rr	Move data memory to A	1	1
MOV	A,#data	Move immediate to A	2	2
MOV	Rr,A	Move A to register	1	1
MOV	@Rr,A	Move A to data memory	1	1
MOV	Rr,#data	Move immediate to register	2	2
MOV	@Rr,#data	Move immediate to data memory	2	2
MOV	A,PSW	Move PSW to A	1	1
MOV	PSW,A	Move A to PSW	1	1
XCH	A,Rr	Exchange A and registers	1	1
XCH	A,@Rr	Exchange A and data memory	1	1
XCHD	A,@Rr	Exchange digit of A and register	1	1
MOVP	A,@A	Move to A from current page	1	2
MOVP3	A,@A	Move to A from Page 3	1	2
TIMER/COUNTER				
MOV	A,T	Read Timer/Counter	1	1
MOV	T,A	Load Timer/Counter	1	1
STRT	T	Start Timer	1	1
STRT	CNT	Start Counter	1	1
STOP	TCNT	Stop Timer/Counter	1	1
EN	TCNTI	Enable Timer/Counter Interrupt	1	1
DIS	TCNTI	Disable Timer/Counter Interrupt	1	1
CONTROL				
EN	DMA	Enable DMA Handshake Lines	1	1
EN	I	Enable IBF interrupt	1	1
DIS	I	Disable IBF interrupt	1	1
EN	FLAGS	Enable Master Interrupts	1	1
SEL	RB0	Select register bank 0	1	1
SEL	RB1	Select register bank 1	1	1
NOP		No Operation	1	1
REGISTERS				
INC	Rr	Increment register	1	1
INC	@Rr	Increment data memory	1	1
DEC	Rr	Decrement register	1	1
SUBROUTINE				
CALL	addr	Jump to subroutine	2	2
RET		Return	1	2
RETR		Return and restore status	1	2
FLAGS				
CLR C		Clear Carry	1	1
CPL C		Complement Carry	1	1
CLR F0		Clear Flag 0	1	1
CPL F0		Complement Flag 0	1	1
CLR F1		Clear F_1 Flag	1	1
CPL F1		Complement F_1 Flag	1	1

Table 3-2. Instruction Set Summary (Con't.)

Mnemonic		Operation Description	Bytes	Cycles
BRANCH				
JMP	addr	Jump unconditional	2	2
JMPP	@A	Jump indirect	1	2
DJNZ	Rr,addr	Decrement register and jump on non-zero	2	2
JC	addr	Jump on Carry=1	2	2
JNC	addr	Jump on Carry=0	2	2
JZ	addr	Jump on A Zero	2	2
JNZ	addr	Jump on A not Zero	2	2
JT0	addr	Jump on T_0=1	2	2
JNT0	addr	Jump on T_0=0	2	2
JT1	addr	Jump on T_1=1	2	2
JNT1	addr	Jump on T_1=0	2	2
JF0	addr	Jump on F_0 Flag=1	2	2
JF1	addr	Jump on F_1 Flag=1	2	2
JTF	addr	Jump on Timer Flag=1	2	2
JNIBF	addr	Jump on IBF Flag=0	2	2
JOBF	addr	Jump on OBF Flag=1	2	2
JBb	addr	Jump on Accumulator Bit	2	2

ALPHABETIC LISTING

ADD A,Rr Add Register Contents to Accumulator

Opcode: | 0 1 1 0 | 1 r_2 r_1 r_0 |

The contents of register 'r' are added to the accumulator. Carry is affected.

(A) ← (A) + (Rr) r=0−7

Example: ADDREG: ADD A,R6 ;ADD REG 6 CONTENTS ;TO ACC

ADD A,@Rr Add Data Memory Contents to Accumulator

Opcode: | 0 1 1 0 | 0 0 0 r |

The contents of the standard data memory location addressed by register 'r' bits 0–5 are added to the accumulator. Carry is affected.

(A) ← (A) + ((Rr)) r=0−1

Example:

```
ADDM: MOV RO,#47      ;MOVE 47 DECIMAL TO REG 0
      ADD A,@R0       ;ADD VALUE OF LOCATION
                      ;47 TO ACC
```

ADD A,#data Add Immediate Data to Accumulator

Opcode: | 0 0 0 0 | 0 0 1 1 | • | d_7 d_6 d_5 d_4 | d_3 d_2 d_1 d_0 |

This is a 2-cycle instruction. The specified data is added to the accumulator. Carry is affected.

(A) ← (A) + data

Example: ADDID: ADD A,#ADDER ;ADD VALUE OF SYMBOL ;'ADDER' TO ACC

ADDC A,Rr Add Carry and Register Contents to Accumulator

Opcode:	0	1	1	1	1	r_2	r_1	r_0

The content of the carry bit is added to accumulator location 0. The contents of register 'r' are then added to the accumulator. Carry is affected.

(A) ← (A) + (Rr) + (C) r=0–7

Example: ADDRGC: ADDC A,R4 ;ADD CARRY AND REG 4
;CONTENTS TO ACC

ADDC A,@Rr Add Carry and Data Memory Contents to Accumulator

Opcode:	0	1	1	1	0	0	0	r

The content of the carry bit is added to accumulator location 0. Then the contents of the standard data memory location addressed by register 'r' bits 0–5 are added to the accumulator. Carry is affected.

(A) ← (A) + ((Rr)) + (C) r=0–1

Example: ADDMC: MOV R1,#40 ;MOV '40' DEC TO REG 1
ADDC A,@R1 ;ADD CARRY AND LOCATION 40
;CONTENTS TO ACC

ADDC A,#data Add Carry and Immediate Data to Accumulator

Opcode:	0	0	0	1	0	0	1	1	•	d_7	d_6	d_5	d_4	d_3	d_2	d_1	d_0

This is a 2-cycle instruction. The content of the carry bit is added to accumulator location 0. Then the specified data is added to the accumulator. Carry is affected.

(A) ← (A) + data + (C)

Example: ADDC A,#255 ;ADD CARRY AND '225' DEC
;TO ACC

ANL A,Rr Logical AND Accumulator With Register Mask

Opcode:	0	1	0	1	1	r_2	r_1	r_0

Data in the accumulator is logically ANDed with the mask contained in working register 'r'.

(A) ← (A) AND (Rr) r=0–7

Example: ANDREG: ANL A,R3 ;'AND' ACC CONTENTS WITH MASK
;MASK IN REG 3

ANL A,@Rr Logical AND Accumulator With Memory Mask

Opcode:	0	1	0	1	0	0	0	r

Data in the accumulator is logically ANDed with the mask contained in the data memory location referenced by register 'r', bits 0–5.

(A) ← (A) AND ((Rr)) r=0–1

Example: ANDDM: MOV R0,#0FFH ;MOVE 'FF' HEX TO REG 0
ANL A,#0AFH ;'AND' ACC CONTENTS WITH
;MASK IN LOCATION 63

ANL A,#data Logical AND Accumulator With Immediate Mask

Opcode:	0 1 0 1	0 0 1 1	•	d_7 d_6 d_5 d_4	d_3 d_2 d_1 d_0

This is a 2-cycle instruction. Data in the accumulator is logically ANDed with an immediately-specified mask.
(A) ← (A) AND data

Example:
```
ANDID: ANL A,#0AFH      ;'AND' ACC CONTENTS
                        ;WITH MASK 10101111
       ANL A,#3+X/Y     ;'AND' ACC CONTENTS
                        ;WITH VALUE OF EXP
                        ;'3+X/Y'
```

ANL Pp,#data Logical AND Port 1–2 With Immediate Mask

Opcode:	1 0 0 1	1 0 p_1 p_0	•	d_7 d_6 d_5 d_4	d_3 d_2 d_1 d_0

This is a 2-cycle instruction. Data on port 'p' is logically ANDed with an immediately-specified mask.
(Pp) ← (Pp) AND data p=1–2

Note: Bits 0-1 of the opcode are used to represent PORT 1 and PORT 2. If you are coding in binary rather than assembly language, the mapping is as follows:

Bits	p1	p0	Port
	0	0	X
	0	1	1
	1	0	2
	1	1	X

Example:
```
ANDP2: ANL P2,#OF0H     ;'AND' PORT 2 CONTENTS
                        ;WITH MASK 'F0' HEX
                        ;(CLEAR P20–23)
```

ANLD Pp,A Logical AND Port 4–7 With Accumulator Mask

Opcode:	1 0 0 1	1 1 p_1 p_0

This is a 2-cycle instruction. Data on port 'p' on the 8243 expander is logically ANDed with the digit mask contained in accumulator bits 0–3.
(Pp) ← (Pp) AND (A0–3) p=4–7

Note: The mapping of Port 'p' to opcode bits p_1,p_0 is as follows:

p_1	p_0	Port
0	0	4
0	1	5
1	0	6
1	1	7

Example:
```
ANDP4: ANLD P4,A        ;'AND' PORT 4 CONTENTS
                        ;WITH ACC BITS 0–3
```

CALL address Subroutine Call

Opcode:

0	a_9	a_8	1	0	1	0	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. The program counter and PSW bits 4–7 are saved in the stack. The stack pointer (PSW bits 0–2) is updated. Program control is then passed to the location specified by 'address'.

Execution continues at the instruction following the CALL upon return from the subroutine.

((SP)) ← (PC), (PSW_{4-7})
(SP) ← (SP) + 1
(PC_{8-9}) ← ($addr_{8-9}$)
(PC_{0-7}) ← ($addr_{0-7}$)

Example: Add three groups of two numbers. Put subtotals in locations 50, 51 and total in location 52.

```
        MOV R0,#50      ;MOVE '50' DEC TO ADDRESS
                        ;REG 0
BEGADD: MOV A,R1        ;MOVE CONTENTS OF REG 1
                        ;TO ACC
        ADD A,R2        ;ADD REG 2 TO ACC
        CALL SUBTOT     ;CALL SUBROUTINE 'SUBTOT'
        ADD A,R3        ;ADD REG 3 TO ACC
        ADD A,R4        ;ADD REG 4 TO ACC
        CALL SUBTOT     ;CALL SUBROUTINE 'SUBTOT'
        ADD A,R5        ;ADD REG 5 TO ACC
        ADD A,R6        ;ADD REG 6 TO ACC
        CALL SUBTOT     ;CALL SUBROUTINE 'SUBTOT'
          .
          .
          .
SUBTOT: MOV @R0,A       ;MOVE CONTENTS OF ACC TO
                        ;LOCATION ADDRESSED BY
                        ;REG 0
        INC R0          ;INCREMENT REG 0
        RET             ;RETURN TO MAIN PROGRAM
```

CLR A Clear Accumulator

Opcode:

0	0	1	0	0	1	1	1

The contents of the accumulator are cleared to zero.
(A) ← 00H

CLR C Clear Carry Bit

Opcode:

1	0	0	1	0	1	1	1

During normal program execution, the carry bit can be set to one by the ADD, ADDC, RLC, CPLC, RRC, and DAA instructions. This instruction resets the carry bit to zero.
(C) ← 0

CLR F1 Clear Flag 1

Opcode:

1	0	1	0	0	1	0	1

The F_1 flag is cleared to zero.
(F_1) ← 0

CLR F0 Clear Flag 0

Opcode: 1 0 0 0 | 0 1 0 1

Flag 0 is cleared to zero.
$(F_0) \leftarrow 0$

CPL A Complement Accumulator

Opcode: 0 0 1 1 | 0 1 1 1

The contents of the accumulator are complemented. This is strictly a one's complement. Each one is changed to zero and vice-versa.
(A) ← NOT (A)

Example: Assume accumulator contains 01101010.

```
CPLA: CPL A                    ;ACC CONTENTS ARE COMPLE-
                               ;MENTED TO 10010101
```

CPL C Complement Carry Bit

Opcode: 1 0 1 0 | 0 1 1 1

The setting of the carry bit is complemented; one is changed to zero, and zero is changed to one.
(C) ← NOT (C)

Example: Set C to one; current setting is unknown.

```
CT01: CLR C                    ;C IS CLEARED TO ZERO
      CPL C                    ;C IS SET TO ONE
```

CPL F0 Complement Flag 0

Opcode: 1 0 0 1 | 0 1 0 1

The setting of Flag 0 is complemented; one is changed to zero, and zero is changed to one.
$F_0 \leftarrow$ NOT (F0)

CPL F1 Complement Flag 1

Opcode: 1 0 1 1 | 0 1 0 1

The setting of the F_1 Flag is complemented; one is changed to zero, and zero is changed to one.
$(F_1) \leftarrow$ NOT (F_1)

DA A Decimal Adjust Accumulator

Opcode:

0	1	0	1	0	1	1	1

The 8-bit accumulator value is adjusted to form two 4-bit Binary Coded Decimal (BCD) digits following the binary addition of BCD numbers. The carry bit C is affected. If the contents of bits 0–3 are greater than nine, or if AC is one, the accumulator is incremented by six.

The four high-order bits are then checked. If bits 4–7 exceed nine, or if C is one, these bits are increased by six. If an overflow occurs, C is set to one; otherwise, it is cleared to zero.

Example: Assume accumulator contains 9AH.

```
DA  A       ;ACC ADJUSTED TO 01H with C set
C   AC   ACC
0   0    9AH   INITIAL CONTENTS
         06H   ADD SIX TO LOW DIGIT
0   0    A1H
         60H   ADD SIX TO HIGH DIGIT
1   0    01H   RESULT
```

DEC A Decrement Accumulator

Opcode:

0	0	0	0	0	1	1	1

The contents of the accumulator are decremented by one.

(A) ← (A) − 1

Example: Decrement contents of data memory location 63.

```
MOV R0,#3FH       ;MOVE '3F' HEX TO REG 0
MOV A,@R0         ;MOVE CONTENTS OF LOCATION 63
                  ;TO ACC
DEC A             ;DECREMENT ACC
MOV @R0,A         ;MOVE CONTENTS OF ACC TO
                  ;LOCATION 63
```

DEC Rr Decrement Register

Opcode:

1	1	0	0	1	r_2	r_1	r_0

The contents of working register 'r' are decremented by one.

(Rr) ← (Rr) − 1 r=0–7

Example: DECR1: DEC R1 ;DECREMENT ADDRESS REG 1

DIS I Disable IBF Interrupt

Opcode:

0	0	0	1	0	1	0	1

The input Buffer Full interrupt is disabled. The interrupt sequence is not initiated by $\overline{WR}$ and $\overline{CS}$, however, an IBF interrupt request is latched and remains pending until an EN I (enable IBF interrupt) instruction is executed.

Note: The IBF flag is set and cleared independent of the IBF interrupt request so that handshaking protocol can continue normally.

DIS TCNTI   Disable Timer/Counter Interrupt

Opcode:

0	0	1	1	0	1	0	1

The timer/counter interrupt is disabled. Any pending timer interrupt request is cleared. The interrupt sequence is not initiated by an overflow, but the timer flag is set and time accumulation continues.

DJNZ Rr, address   Decrement Register and Test

Opcode:

1	1	1	0	1	r_2	r_1	r_0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Register 'r' is decremented and tested for zero. If the register contains all zeros, program control falls through to the next instruction. If the register contents are not zero, control jumps to the specified address within the current page.

$(Rr) \leftarrow (Rr) - 1$

If $R \neq 0$, then;

$(PC_{0-7}) \leftarrow addr$

Note: A 10-bit address specification does not cause an error if the DJNZ instruction and the jump target are on the same page. If the DJNZ instruction begins in location 255 of a page, it will jump to a target address on the following page. Otherwise, it is limited to a jump within the current page.

Example: Increment values in data memory locations 50–54.

```
          MOV R0,#50          ;MOVE '50' DEC TO ADDRESS
                              ;REG 0
          MOV R3,#05          ;MOVE '5' DEC TO COUNTER
                              ;REG 3
INCRT:    INC @R0             ;INCREMENT CONTENTS OF
                              ;LOCATION ADDRESSED BY
                              ;REG 0
          INC R0              ;INCREMENT ADDRESS IN REG 0
          DJNZ R3,INCRT       ;DECREMENT REG 3——JUMP TO
                              ;'INCRT' IF REG 3 NONZERO
          NEXT——              ;'NEXT' ROUTINE EXECUTED
                              ;IF R3 IS ZERO
```

EN DMA   Enable DMA Handshake Lines

Opcode:

1	1	1	0	0	1	0	1

DMA handshaking is enabled using P_{26} as DMA request (DRQ) and P_{27} as DMA acknowledge ($\overline{DACK}$). The $\overline{DACK}$ line forces $\overline{CS}$ and A_0 low internally and clears DRQ.

EN FLAGS   Enable Master Interrupts

Opcode:

1	1	1	1	0	1	0	1

The Output Buffer Full (OBF) and the Input Buffer Full (IBF) flags (IBF is inverted) are routed to P_{24} and P_{25}. For proper operation, a "1" should be written to P_{25} and P_{24} before the EN FLAGS instruction. A "0" written to P_{24} or P_{25} disables the pin.

EN I Enable IBF Interrupt

Opcode:

0	0	0	0	0	1	0	1

The Input Buffer Full interrupt is enabled. A low signal on $\overline{WR}$ and $\overline{CS}$ initiates the interrupt sequence.

EN TCNTI Enable Timer/Counter Interrupt

Opcode:

0	0	1	0	0	1	0	1

The timer/counter interrupt is enabled. An overflow of this register initiates the interrupt sequence.

IN A,DBB Input Data Bus Buffer Contents to Accumulator

Opcode:

0	0	1	0	0	0	1	0

Data in the DBBIN register is transferred to the accumulator and the Input Buffer Full (IBF) flag is set to zero.
(A) ← (DBB)
(IBF) ← 0

Example:
```
INDBB: IN A,DBB          ;INPUT DBBIN CONTENTS TO
                         ;ACCUMULATOR
```

IN A,Pp Input Port 1-2 Data to Accumulator

Opcode:

0	0	0	0	1	0	p_1	p_0

This is a 2-cycle instruction. Data present on port 'p' is transferred (read) to the accumulator.
(A) ← (Pp) p=1–2 (see ANL instruction)

Example:
```
INP12: IN A,P1           ;INPUT PORT 1 CONTENTS
                         ;TO ACC
       MOV R6,A          ;MOVE ACC CONTENTS TO
                         ;REG 6
       IN A,P2           ;INPUT PORT 2 CONTENTS
                         ;TO ACC
       MOV R7,A          ;MOVE ACC CONTENTS TO REG 7
```

INC A Increment Accumulator

Opcode:

0	0	0	1	0	1	1	1

The contents of the accumulator are incremented by one.
(A) ← (A) + 1

Example: Increment contents of location 10 in data memory.
```
INCA: MOV R0,#10         ;MOV '10' DEC TO ADDRESS
                         ;REG 0
      MOV A,@R0          ;MOVE CONTENTS OF LOCATION
                         ;10 TO ACC
      INC A              ;INCREMENT ACC
      MOV @R0,A          ;MOVE ACC CONTENTS TO
                         ;LOCATION 10
```

INC Rr Increment Register

Opcode:

0	0	0	1	1	r_2	r_1	r_0

The contents of working register 'r' are incremented by one.

(Rr) ← (Rr) + 1   r=0–7

Example: INCR0: INC R0   ;INCREMENT ADDRESS REG 0

INC @Rr Increment Data Memory Location

Opcode:

0	0	0	1	0	0	0	r

The contents of the resident data memory location addressed by register 'r' bits 0–5 are incremented by one.

((Rr)) ← ((Rr)) + 1   r=0–1

Example: INCDM: MOV R1,#OFFH   ;MOVE ONES TO REG 1

INC @R1   ;INCREMENT LOCATION 63

JBb address Jump If Accumulator Bit is Set

Opcode:

b_2	b_1	b_0	1	0	0	1	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Control passes to the specified address if accumulator bit 'b' is set to one.

(PC_{0-7}) ← addr   if b=1

(PC) ← (PC) + 2   if b=0

Example: JB4IS1: JB4 NEXT   ;JUMP TO 'NEXT' ROUTINE

;IF ACC BIT 4=1

JC address Jump If Carry Is Set

Opcode:

1	1	1	1	0	1	1	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Control passes to the specified address if the carry bit is set to one.

(PC_{0-7}) ← addr   if C=1

(PC) ← (PC) + 2   if C=0

Example: JC1: JC OVERFLOW   ;JUMP TO 'OVFLOW' ROUTINE

;IF C=1

JF0 address Jump If Flag 0 Is Set

Opcode:

1	0	1	1	0	1	1	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Control passes to the specified address if flag 0 is set to one.

(PC_{0-7}) ← addr   if F_0=1

Example: JF0IS1: JF0 TOTAL   ;JUMP TO 'TOTAL' ROUTINE

;IF F_0=1

JF1 address   Jump If C/D Flag (F1) Is Set

Opcode:

0	1	1	1	0	1	1	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Control passes to the specified address if the C/D flag (F_1) is set to one.

$(PC_{0-7}) \leftarrow$ addr   if $F_1=1$

Example: JF 1IS1: JF1 FILBUF   ;JUMP TO 'FILBUF'
;ROUTINE IF $F_1=1$

JMP address   Direct Jump Within 1K Block

Opcode:

a_{10}	a_9	a_8	0	0	1	0	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Bits 0–9 of the program counter are replaced with the directly-specified address.

$(PC_{8-9}) \leftarrow$ addr 8–9

$(PC_{0-7}) \leftarrow$ addr 0–7

Example:

```
JMP SUBTOT      ;JUMP TO SUBROUTINE 'SUBTOT'
JMP $-6         ;JUMP TO INSTRUCTION SIX LOCATIONS
                ;BEFORE CURRENT LOCATION
JMP 2FH         ;JUMP TO ADDRESS '2F' HEX
```

JMPP @A   Indirect Jump Within Page

Opcode:

1	0	1	1	0	0	1	1

This is a 2-cycle instruction. The contents of the program memory location pointed to by the accumulator are substituted for the 'page' portion of the program counter (PC 0–7).

$(PC_{0-7}) \leftarrow ((A))$

Example: Assume accumulator contains OFH

```
JMPPAG: JMPP @A   ;JMP TO ADDRESS STORED IN
                  ;LOCATION 15 IN CURRENT PAGE
```

JNC address   Jump If Carry Is Not Set

Opcode:

1	1	1	0	0	1	1	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Control passes to the specified address if the carry bit is not set, that is, equals zero.

$(PC_{0-7}) \leftarrow$ addr   if C=0

Example: JC0: JNC NOVFLO   ;JUMP TO 'NOVFLO' ROUTINE
;IF C=0

JNIBF address   Jump If Input Buffer Full Flag Is Low

Opcode:

1	1	0	1	0	1	1	0	•	a_7	a_6	a_5	a_4	a_3	a_2	a_1	a_0

This is a 2-cycle instruction. Control passes to the specified address if the Input Buffer Full flag is low (IBF=0).

$(PC_{0-7}) \leftarrow$ addr   if IBF=0

Example: LOC 3:JNIBF LOC 3   ;JUMP TO SELF IF IBF=0
;OTHERWISE CONTINUE

JNTO address Jump If TEST 0 Is Low

Opcode:	0 0 1 0	0 1 1 0	• a7 a6 a5 a4 a3 a2 a1 a0

This is a 2-cycle instruction. Control passes to the specified address, if the TEST 0 signal is low. Pin is sampled during SYNC.

$(PC_{0-7}) \leftarrow$ addr if $T_0=0$

Example: JTOLOW: JNTO 60 ;JUMP TO LOCATION 60 DEC ;IF $T_0=0$

JNT1 address Jump If TEST 1 Is Low

Opcode:	0 1 0 0	0 1 1 0	• a7 a6 a5 a4 a3 a2 a1 a0

This is a 2-cycle instruction. Control passes to the specified address if the TEST 1 signal is low. Pin is sampled during SYNC.

$(PC_{0-7}) \leftarrow$ addr if $T_1=0$

Example: JT1LOW: JNT1 OBBH ;JUMP TO LOCATION 'BB' HEX ;IF $T_1=0$

JNZ address Jump If Accumulator Is Not Zero

Opcode:	1 0 0 1	0 1 1 0	• a7 a6 a5 a4 a3 a2 a1 a0

This is a 2-cycle instruction. Control passes to the specified address if the accumulator contents are nonzero at the time this instruction is executed.

$(PC_{0-7}) \leftarrow$ addr if $A \neq 0$

Example: JACCNO: JNZ OABH ;JUMP TO LOCATION 'AB' HEX ;IF ACC VALUE IS NONZERO

JOBF Address Jump If Output Buffer Full Flag Is Set

Opcode:	1 0 0 0	0 1 1 0	• a7 a6 a5 a4 a3 a2 a1 a0

This is a 2-cycle instruction. Control passes to the specified address if the Output Buffer Full (OBF) flag is set (=1) at the time this instruction is executed.

$(PC_{0-7}) \leftarrow$ addr if OBF=1

Example: JOBFHI: JOBF OAAH ;JUMP TO LOCATION 'AA' HEX ;IF OBF=1

JTF address Jump If Timer Flag Is Set

Opcode:	0 0 0 1	0 1 1 0	• a7 a6 a5 a4 a3 a2 a1 a0

This is a 2-cycle instruction. Control passes to the specified address if the timer flag is set to one, that is, the timer/counter register overflows to zero. The timer flag is cleared upon execution of this instruction. (This overflow initiates an interrupt service sequence if the timer-overflow interrupt is enabled.)

$(PC_{0-7}) \leftarrow$ addr if TF=1

Example: JTF1: JTF TIMER ;JUMP TO 'TIMER' ROUTINE ;IF TF=1

JTO address Jump If TEST 0 Is High

Opcode:	0 0 1 1	0 1 1 0	•	a_7 a_6 a_5 a_4	a_3 a_2 a_1 a_0

This is a 2-cycle instruction. Control passes to the specified address if the TEST 0 signal is high (= 1). Pin is sampled during SYNC.

$(PC_{0-7}) \leftarrow$ addr if $T_0 = 1$

Example: JTOHI: JTO 53 ;JUMP TO LOCATION 53 DEC
;IF $T_0 = 1$

JT1 address Jump If TEST 1 Is High

Opcode:	0 1 0 1	0 1 1 0	•	a_7 a_6 a_5 a_4	a_3 a_2 a_1 a_0

This is a 2-cycle instruction. Control passes to the specified address if the TEST 1 signal is high (= 1). Pin is sampled during SYNC.

$(PC_{0-7}) \leftarrow$ addr if $T_1 = 1$

Example: JT1HI: JT1 COUNT ;JUMP TO 'COUNT' ROUTINE
;IF $T_1 = 1$

JZ address Jump If Accumulator Is Zero

Opcode:	1 1 0 0	0 1 1 0	•	a_7 a_6 a_5 a_4	a_3 a_2 a_1 a_0

This is a 2-cycle instruction. Control passes to the specified address if the accumulator contains all zeros at the time this instruction is executed.

$(PC_{0-7}) \leftarrow$ addr if A=0

Example: JACCO: JZ OA3H ;JUMP TO LOCATION 'A3' HEX
;IF ACC VALUE IS ZERO

MOV A,#data Move Immediate Data to Accumulator

Opcode:	0 0 1 0	0 0 1 1	•	d_7 d_6 d_5 d_4	d_3 d_2 d_1 d_0

This is a 2-cycle instruction. The 8-bit value specified by 'data' is loaded in the accumulator.

$(A) \leftarrow$ data

Example: MOV A,#OA3H ;MOV 'A3' HEX TO ACC

MOV A,PSW Move PSW Contents to Accumulator

Opcode:	1 1 0 0	0 1 1 1

The contents of the program status word are moved to the accumulator.

$(A) \leftarrow (PSW)$

Example: Jump to 'RB1SET' routine if bank switch, PSW bit 4, is set.

```
BSCHK: MOV A,PSW     ;MOV PSW CONTENTS TO ACC
       JB4 RB1 SET   ;JUMP TO 'RB1SET' IF ACC
                     ;BIT 4=1
```

MOV A, Rr **Move Register Contents to Accumulator**

Opcode:	1	1	1	1	1	r_2	r_1	r_0

Eight bits of data are moved from working register 'r' into the accumulator.

(A) ← (Rr) r=0–7

Example:
```
MAR: MOV A,R3          ;MOVE CONTENTS OF REG 3
                       ;TO ACC
```

MOV A,@Rr **Move Data Memory Contents to Accumulator**

Opcode:	1	1	1	1	0	0	0	r

The contents of the data memory location addressed by bits 0–5 of register 'r' are moved to the accumulator. Register 'r' contents are unaffected.

(A) ← ((Rr)) r=0–1

Example: Assume R1 contains 00110110.
```
MADM: MOV A,@R1        ;MOVE CONTENTS OF DATA MEM
                       ;LOCATION 54 TO ACC
```

MOV A,T **Move Timer/Counter Contents to Accumulator**

Opcode:	0	1	0	0	0	0	1	0

The contents of the timer/event-counter register are moved to the accumulator. The timer/event-counter is not stopped.

(A) ← (T)

Example: Jump to "EXIT" routine when timer reaches '64', that is, when bit 6 is set—assuming initialization to zero.
```
TIMCHK: MOV A,T        ;MOVE TIMER CONTENTS TO
                       ;ACC
        JB6 EXIT       ;JUMP TO 'EXIT' IF ACC BIT
                       ;6=1
```

MOV PSW,A **Move Accumulator Contents to PSW**

Opcode:	1	1	0	1	0	1	1	1

The contents of the accumulator are moved into the program status word. All condition bits and the stack pointer are affected by this move.

(PSW) ← (A)

Example: Move up stack pointer by two memory locations, that is, increment the pointer by one.
```
INCPTR: MOV A,PSW      ;MOVE PSW CONTENTS TO ACC
        INC A          ;INCREMENT ACC BY ONE
        MOV PSW,A      ;MOVE ACC CONTENTS TO PSW
```

MOV Rr,A Move Accumulator Contents to Register

Opcode:

1	0	1	0	1	r_2	r_1	r_0

The contents of the accumulator are moved to register 'r'.

(Rr) ← (A) r=0–7

Example:
```
MRA MOV R0,A          ;MOVE CONTENTS OF ACC TO
                      ;REG 0
```

MOV Rr,#data Move Immediate Data to Register

Opcode:

1	0	1	1	1	r_2	r_1	r_0	•	d_7	d_6	d_5	d_4	d_3	d_2	d_1	d_0

This a 2-cycle instruction. The 8-bit value specified by 'data' is moved to register 'r'.

(Rr) ← data r=0–7

Example:
```
MIR4: MOV R4,#HEXTEN  ;THE VALUE OF THE SYMBOL
                      ;'HEXTEN' IS MOVED INTO
                      ;REG 4
MIR5: MOV R5;#PI*(R*R) ;THE VALUE OF THE
                      ;EXPRESSION 'PI*(R*R)'
                      ;IS MOVED INTO REG 5
MIR6: MOV R6,#OADH    ;'AD' HEX IS MOVED INTO
                      ;REG 6
```

MOV @Rr,A Move Accumulator Contents to Data Memory

Opcode:

1	0	1	0	0	0	0	r

The contents of the accumulator are moved to the data memory location whose address is specified by bits 0–5 of register 'r'. Register 'r' contents are unaffected.

((Rr)) ← (A) r=0–1

Example: Assume R0 contains 11000111.
```
MDMA: MOV @R,A        ;MOVE CONTENTS OF ACC TO
                      ;LOCATION 7 (REG)
```

MOV @Rr,#data Move Immediate Data to Data Memory

Opcode:

1	0	1	1	0	0	0	r	•	d_7	d_6	d_5	d_4	d_3	d_2	d_1	d_0

This is a 2-cycle instruction. The 8-bit value specified by 'data' is moved to the standard data memory location addressed by register 'r', bit 0–5.

((Rr)) ← data r=0–1

Example: Move the hexadecimal value AC3F to locations 62–63.
```
MIDM: MOV R0,#62      ;MOVE '62' DEC TO ADDR REGO
      MOV @RO,#OACH   ;MOVE 'AC' HEX TO LOCATION 62
      INC RO          ;INCREMENT REG 0 TO '63'
      MOV @RO,#3FH    ;MOVE '3F' HEX TO LOCATION 63
```

MOV STS,A Move Accumulator Contents to STS Register

Opcode:

1	0	0	1	0	0	0	0

The contents of the accumulator are moved into the status register. Only bits 4–7 are affected.

$(STS_{4-7}) \leftarrow (A_{4-7})$

Example: Set ST_4–ST_7 to "1".

```
MSTS: MOV A,#0F0H        ;SET ACC
      MOV STS,A          ;MOVE TO STS
```

MOV T,A Move Accumulator Contents to Timer/Counter

Opcode:

0	1	1	0	0	0	1	0

The contents of the accumulator are moved to the timer/event-counter register.

$(T) \leftarrow (A)$

Example: Initialize and start event counter.

```
INITEC: CLR A            ;CLEAR ACC TO ZEROS
        MOV T,A          ;MOVE ZEROS TO EVENT COUNTER
        STRT CNT         ;START COUNTER
```

MOVD A,Pp Move Port 4–7 Data to Accumulator

Opcode:

0	0	0	0	1	1	p_1	p_0

This is a 2-cycle instruction. Data on 8243 port 'p' is moved (read) to accumulator bits 0–3. Accumulator bits 4–7 are zeroed.

$(A_{0-3}) \leftarrow Pp$ $\quad p=4-7$

$(A_{4-7}) \leftarrow 0$

Note: Bits 0–1 of the opcode are used to represent PORTS 4–7. If you are coding in binary rather than assembly language, the mapping is as follows:

Bits p_1	p_0	Port
0	0	4
0	1	5
1	0	6
1	1	7

Example:

```
INPPT5: MOVD A,P5        ;MOVE PORT 5 DATA TO ACC
                         ;BITS 0-3, ZERO ACC BITS 4-7
```

MOVD Pp,A Move Accumulator Data to Port 4, 5, 6 and 7

Opcode:

0	0	1	1	1	1	p_1	p_0

This is a 2-cycle instruction. Data in accumulator bits 0–3 is moved (written) to 8243 port 'p'. Accumulator bits 4–7 are unaffected. (See NOTE above regarding port mapping.)

$(Pp) \leftarrow (A_{0-3})$ $\quad p=4-7$

Example: Move data in accumulator to ports 4 and 5.

```
OUTP45: MOVD P4,A        ;MOVE ACC BITS 0-3 TO PORT 4
        SWAP A           ;EXCHANGE ACC BITS 0-3 AND 4-7
        MOVD P5,A        ;MOVE ACC BITS 0-3 TO PORT 5
```

MOVP A,@A Move Current Page Data to Accumulator

Opcode:

1	0	1	0	0	0	1	1

This is a 2-cycle instruction. The contents of the program memory location addressed by the accumulator are moved to the accumulator. Only bits 0–7 of the program counter are affected, limiting the program memory reference to the current page. The program counter is restored following this operation.

(A) ← ((A))

Note: This is a 1-byte, 2-cycle instruction. If it appears in location 255 of a program memory page, @A addresses a location in the following page.

Example:

```
MOV128: MOV   A,#128      ;MOVE '128' DEC TO ACC
        MOVP A,@A         ;CONTENTS OF 129TH LOCATION
                          ;IN CURRENT PAGE ARE MOVED TO
                          ;ACC
```

MOVP3 A,@A Move Page 3 Data to Accumulator

Opcode:

1	1	1	0	0	0	1	1

This is a 2-cycle instruction. The contents of the program memory location within page 3, addressed by the accumulator, are moved to the accumulator. The program counter is restored following this operation.

(A) ← ((A)) within page 3

Example: Look up ASCII equivalent of hexadecimal code in table contained at the beginning of page 3. Note that ASCII characters are designated by a 7-bit code; the eighth bit is always reset.

```
TABSCH: MOV A,#OB8H       ;MOVE 'B8' HEX TO ACC (10111000)
        ANL A,#7FH        ;LOGICAL AND ACC TO MASK BIT
                          ;7 (00111000)
        MOVP3, A,@A       ;MOVE CONTENTS OF LOCATION
                          ;'38' HEX IN PAGE 3 TO ACC
                          ;(ASCII '8')
```

Access contents of location in page 3 labelled TAB1. Assume current program location is not in page 3.

```
TABSCH: MOV A,#TAB1       ;ISOLATE BITS 0-7
                          ;OF LABEL
                          ;ADDRESS VALUE
        MOVP3 A,@A        ;MOVE CONTENT OF PAGE 3
                          ;LOCATION LABELED 'TAB1'
                          ;TO ACC
```

NOP The NOP Instruction

Opcode:

0	0	0	0	0	0	0	0

No operation is performed. Execution continues with the following instruction.

ORL A,Rr Logical OR Accumulator With Register Mask

Opcode:

0	1	0	0	1	r_2	r_1	r_0

Data in the accumulator is logically ORed with the mask contained in working register 'r'.

(A) ← (A) OR (Rr)   r=0–7

Example:

```
ORREG: ORL A,R4           ;'OR' ACC CONTENTS WITH
                          ;MASK IN REG 4
```

ORL A,@Rr Logical OR Accumulator With Memory Mask

Opcode:	0	1	0	0	0	0	0	r

Data in the accumulator is logically ORed with the mask contained in the data memory location referenced by register 'r', bits 0–5.

(A) ← (A) OR ((Rr)) r=0–1

Example:
```
ORDM: MOVE R0,#3FH     ;MOVE '3F' HEX TO REG 0
      ORL A,@R0        ;'OR' ACC CONTENTS WITH MASK
                       ;IN LOCATION 63
```

ORL A,#data Logical OR Accumulator With Immediate Mask

Opcode: 0 1 0 0 | 0 0 1 1 • d_7 d_6 d_5 d_4 | d_3 d_2 d_1 d_0

This is a 2-cycle instruction. Data in the accumulator is logically ORed with an immediately-specified mask.

(A) ← (A) OR data

Example:
```
ORID: ORL A,#'X'       ;'OR' ACC CONTENTS WITH MASK
                       ;01011000 (ASCII VALUE OF 'X')
```

ORL Pp,#data Logical OR Port 1–2 With Immediate Mask

Opcode: 1 0 0 0 | 1 0 p_1 p_0 • d_7 d_6 d_5 d_4 | d_3 d_2 d_1 d_0

This is a 2-cycle instruction. Data on port 'p' is logically ORed with an immediately-specified mask.

(Pp) ← (Pp) OR data p=1–2 (see OUTL instruction)

Example:
```
ORP1: ORL P1,#OFFH     ;'OR' PORT 1 CONTENTS WITH
                       ;MASK 'FF' HEX (SET PORT 1
                       'TO ALL ONES)
```

ORLD Pp,A Logical OR Port 4–7 With Accumulator Mask

Opcode:	1	0	0	0	1	1	p_1	p_0

This is a 2-cycle instruction. Data on 8243 port 'p' is logically ORed with the digit mask contained in accumulator bits 0–3,

(Pp) (Pp) OR (A_{0-3}) p=4–7 (See MOVD instruction)

Example:
```
ORP7: ORLD P7,A        ;'OR' PORT 7 CONTENTS
                       ;WITH ACC BITS 0-3
```

OUT DBB,A Output Accumulator Contents to Data Bus Buffer

Opcode:	0	0	0	0	0	0	1	0

Contents of the accumulator are transferred to the Data Bus Buffer Output register and the Output Buffer Full (OBF) flag is set to one.

(DBB) ← (A)

OBF ← 1

Example:
```
OUTDBB: OUT DBB,A      ;OUTPUT THE CONTENTS OF
                       ;THE ACC TO DBBOUT
```

OUTL Pp,A Output Accumulator Data to Port 1 and 2

Opcode:	0	0	1	1	1	0	p_1	p_0

This is a 2-cycle instruction. Data residing in the accumulator is transferred (written) to port 'p' and latched.
(Pp) ← (A) P=1–2

Note: Bits 0–1 of the opcode are used to represent PORT 1 and PORT 2. If you are coding in binary rather than assembly language, the mapping is as follows:

Bits	p1	p0	Port
	0	0	X
	0	1	1
	1	0	2
	1	1	X

Example:

```
OUTLP: MOV A,R7     ;MOVE REG 7 CONTENTS TO ACC
       OUTL P2,A    ;OUTPUT ACC CONTENTS TO PORT2
       MOV A,R6     ;MOVE REG 6 CONTENTS TO ACC
       OUTL P1,A    ;OUTPUT ACC CONTENTS TO PORT 1
```

RET Return Without PSW Restore

Opcode:	1	0	0	0	0	0	1	1

This is a 2-cycle instruction. The stack pointer (PSW bits 0–2) is decremented. The program counter is then restored from the stack. PSW bits 4–7 are not restored.
(SP) ← (SP) − 1
(PC) ← ((SP))

RETR Return With PSW Restore

Opcode:	1	0	0	1	0	0	1	1

This is a 2-cycle instruction. The stack pointer is decremented. The program counter and bits 4–7 of the PSW are then restored from the stack. Note that RETR should be used to return from an interrupt, but should not be used within the interrupt service routine as it signals the end of an interrupt routine.
(SP) ← (SP) − 1
(PC) ← ((SP))
(PSW_{4-7}) ← ((SP))

RL A Rotate Left Without Carry

Opcode:	1	1	1	0	0	1	1	1

The contents of the accumulator are rotated left one bit. Bit 7 is rotated into the bit 0 position.
(A_{n+1}) ← (A_n) n=0–6
(A_0) ← (A_7)

Example: Assume accumulator contains 10110001.

```
RLNC: RL A     ;NEW ACC CONTENTS ARE 01100011
```

RLC A Rotate Left Through Carry

Opcode:

1	1	1	1	0	1	1	1

The contents of the accumulator are rotated left one bit. Bit 7 replaces the carry bit; the carry bit is rotated into the bit 0 position.

$(A_{n+1}) \leftarrow (A_n)$ $n=0-6$

$(A_0) \leftarrow (C)$

$(C) \leftarrow (A7)$

Example: Assume accumulator contains a 'signed' number; isolate sign without changing value.

```
RLTC: CLR C           ;CLEAR CARRY TO ZERO
      RLC A           ;ROTATE ACC LEFT, SIGN
                      ;BIT (7) IS PLACED IN CARRY
      RR A            ;ROTATE ACC RIGHT — VALUE
                      ;(BITS 0-6) IS RESTORED,
                      ;CARRY UNCHANGED, BIT 7
                      ;IS ZERO
```

RR A Rotate Right Without Carry

Opcode:

0	1	1	1	0	1	1	1

The contents of the accumulator are rotated right one bit. Bit 0 is rotated into the bit 7 position.

$(A_n) \leftarrow (A_{n+1})$ $n=0-6$

$(A_7) \leftarrow (A_0)$

Example: Assume accumulator contains 10110001.

```
RRNC: RRA             ;NEW ACC CONTENTS ARE 11011000
```

RRC A Rotate Right Through Carry

Opcode:

0	1	1	0	0	1	1	1

The contents of the accumulator are rotated right one bit. Bit 0 replaces the carry bit; the carry bit is rotated into the bit 7 position.

$(A_n) \leftarrow (A_{n+1})$ $n=0-6$

$(A_7) \leftarrow (C)$

$(C) \leftarrow (A_0)$

Example: Assume carry is not set and accumulator contains 10110001.

```
RRTC: RRCA            ;CARRY IS SET AND ACC
                      ;CONTAINS 01011000
```

SEL RB0 Select Register Bank 0

Opcode:

1	1	0	0	0	1	0	1

PSW BIT 4 is set to zero. References to working registers 0–7 address data memory locations 0–7. This is the recommended setting for normal program execution.

$(BS) \leftarrow 0$

SEL RB1 Select Register Bank 1

Opcode:	1	1	0	1	0	1	0	1

PSW bit 4 is set to one. References to working registers 0–7 address data memory locations 24–31. This is the recommended setting for interrupt service routines, since locations 0–7 are left intact. The setting of PSW bit 4 in effect at the time of an interrupt is restored by the RETR instruction when the interrupt service routine is completed.

(BS) ← 1

Example: Assume an IBF interrupt has occurred, control has passed to program memory location 3, and PSW bit 4 was zero before the interrupt.

```
LOC3: JMP INIT              ;JUMP TO ROUTINE 'INIT'
          .
          .
          .
INIT: MOV R7,A              ;MOV ACC CONTENTS TO
                            ;LOCATION 7
      SEL RB1               ;SELECT REG BANK 1
      MOV R7,#OFAH          ;MOVE 'FA' HEX TO LOCATION 31
          .
          .
          .
      SEL RB0               ;SELECT REG BANK 0
      MOV A,R7              ;RESTORE ACC FROM LOCATION 7
      RETR                  ;RETURN--RESTORE PC AND PSW
```

STOP TCNT Stop Timer/Event Counter

Opcode:	0	1	1	0	0	1	0	1

This instruction is used to stop both time accumulation and event counting.

Example: Disable interrupt, but jump to interrupt routine after eight overflows and stop timer. Count overflows in register 7.

```
START: DIS TCNTI            ;DISABLE TIMER INTERRUPT
       CLR A                ;CLEAR ACC TO ZERO
       MOV T,A              :MOV ZERO TO TIMER
       MOV R7,A             :MOVE ZERO TO REG 7
       STRT T               ;START TIMER
MAIN:  JTF COUNT            ;JUMP TO ROUTINE 'COUNT'
                            ;IF TF=1 AND CLEAR TIMER FLAG
       JMP MAIN             ;CLOSE LOOP
COUNT: INC R7               ;INCREMENT REG 7
       MOV A,R7             ;MOVE REG 7 CONTENTS TO ACC
       JB3 INT              ;JUMP TO ROUTINE 'INT' IF ACC
                            ;BIT 3 IS SET (REG 7=8)
       JMP MAIN             ;OTHERWISE RETURN TO ROUTINE
                            ;MAIN
          .
          .
          .
INT:   STOP TCNT            ;STOP TIMER
       JMP 7H               ;JUMP TO LOCATION 7 (TIMER
                            ;INTERRUPT ROUTINE)
```

STRT CNT Start Event Counter

Opcode:	0	1	0	0	0	1	0	1

The TEST 1 (T_1) pin is enabled as the event-counter input and the counter is started. The event-counter register is incremented with each high to low transition on the T_1 pin.

Example: Initialize and start event counter. Assume overflow is desired with first T_1 input.

```
STARTC: EN TCNTI        ;ENABLE COUNTER INTERRUPT
        MOV A,#OFFH     ;MOVE 'FF' HEX (ONES) TO
                        ;ACC
        MOV T,A         ;MOVE ONES TO COUNTER
        STRT CNT        ;INPUT AND START
```

STRT T Start Timer

Opcode:	0	1	0	1	0	1	0	1

Timer accumulation is initiated in the timer register. The register is incremented every 32 instruction cycles. The prescaler which counts the 32 cycles is cleared but the timer register is not.

Example: Initialize and start timer.

```
STARTT: EN TCNTI        ;ENABLE TIMER INTERRUPT
        CLR A           ;CLEAR ACC TO ZEROS
        MOV T,A         ;MOVE ZEROS TO TIMER
        STRT T          ;START TIMER
```

SWAP A Swap Nibbles Within Accumulator

Opcode:	0	1	0	0	0	1	1	1

Bits 0–3 of the accumulator are swapped with bits 4–7 of the accumulator.

$(A_{4-7}) \longleftrightarrow (A_{0-3})$

Example: Pack bits 0–3 of locations 50–51 into location 50.

```
PCKDIG: MOV R0,#50      ;MOVE '50' DEC TO REG 0
        MOV R1,#51      ;MOVE '51' DEC TO REG 1
        XCHD A,@R0      ;EXCHANGE BIT 0-3 OF ACC
                        ;AND LOCATION 50
        SWAP A          ;SWAP BITS 0-3 AND 4-7 OF ACC
        XCHD A,@R1      ;EXCHANGE BITS 0-3 OF ACC AND
                        ;LOCATION 51
        MOV @R0,A       ;MOVE CONTENTS OF ACC TO
                        ;LOCATION 51
```

XCH A,Rr Exchange Accumulator-Register Contents

Opcode:	0	0	1	0	1	r_2	r_1	r_0

The contents of the accumulator and the contents of working register 'r' are exchanged.

$(A) \longleftrightarrow (Rr)$ $r=0-7$

Example: Move PSW contents to Reg 7 without losing accumulator contents.

```
XCHAR7: XCH A,R7        ;EXCHANGE CONTENTS OF REG 7
                        ;AND ACC
        MOV A,PSW       ;MOVE PSW CONTENTS TO ACC
        XCH A,R7        ;EXCHANGE CONTENTS OF REG 7
                        ;AND ACC AGAIN
```

XCH A,@Rr Exchange Accumulator and Data Memory Contents

Opcode:

0	0	1	0	0	0	0	r

The contents of the accumulator and the contents of the data memory location addressed by bits 0–5 of register 'r' are exchanged. Register 'r' contents are unaffected.

(A) ⟷ ((Rr)) r=0–1

Example: Decrement contents of location 52.

```
DEC52: MOV R0,#52       ;MOVE '52' DEC TO ADDRESS
                        ;REG 0
       XCH A,@R0        ;EXCHANGE CONTENTS OF ACC
                        ;AND LOCATION 52
       DEC A            ;DECREMENT ACC CONTENTS
       XCH A,@R0        ;EXCHANGE CONTENTS OF ACC
                        ;AND LOCATION 52 AGAIN
```

XCHD A,@Rr Exchange Accumulator and Data Memory 4-bit Data

Opcode:

0	0	1	1	0	0	0	r

This instruction exchanges bits 0–3 of the accumulator with bits 0–3 of the data memory location addressed by bits 0–5 of register 'r'. Bits 4–7 of the accumulator, bits 4–7 of the data memory location, and the contents of register 'r' are unaffected.

$(A_{0-3}) \longleftrightarrow ((Rr_{0-3}))$ r=0–1

Example: Assume program counter contents have been stacked in locations 22–23.

```
XCHNIB: MOV R0,#23      ;MOVE '23' DEC TO REG 0
        CLR A           ;CLEAR ACC TO ZEROS
        XCHD A,@R0      ;EXCHANGE BITS 0-3 OF ACC
                        ;AND LOCATION 23 (BITS 8-11
                        ;OF PC ARE ZEROED, ADDRESS
                        ;REFERS TO PAGE 0)
```

XRL A,Rr Logical XOR Accumulator With Register Mask

Opcode:

1	1	0	1	1	r_2	r_1	r_0

Data in the accumulator is EXCLUSIVE ORed with the mask contained in working register 'r'.

(A) ← (A) XOR (Rr) r=0–7

Example:

```
XORREG: XRL A,R5        ;'XOR' ACC CONTENTS WITH
                        ;MASK IN REG 5
```

XRL A,@Rr Logical XOR Accumulator With Memory Mask

Opcode:

1	1	0	1	0	0	0	r

Data in the accumulator is EXCLUSIVE ORed with the mask contained in the data memory location addressed by register 'r', bits 0–5.

(A) ← (A) XOR ((Rr)) r=0–1

Example:

```
XORDM: MOV R1,#20H      ;MOVE '20' HEX TO REG 1
       XRL A,@R1        ;'XOR' ACC CONTENTS WITH MASK
                        ;IN LOCATION 32
```

XRL A,#data Logical XOR Accumulator With Immediate Mask

Opcode:

1	1	0	1	0	0	1	1	•	d_7	d_6	d_5	d_4	d_3	d_2	d_1	d_0

This is a 2-cycle instruction. Data in the accumulator is EXCLUSIVE ORed with an immediately-specified mask.

(A) ← (A) XOR data

Example:

```
XORID: XOR A,#HEXTEN       ;XOR CONTENTS OF ACC WITH
                           ;MASK EQUAL VALUE OF SYMBOL
                           ;'HEXTEN'
```

Single-step, Programming and Power-down Modes

4

CHAPTER 4
SINGLE-STEP, PROGRAMMING, AND POWER-DOWN MODES

SINGLE-STEP

The UPI family has a single-step mode which allows the user to manually step through his program one instruction at a time. While stopped, the address of the next instruction to be fetched is available on PORT 1 and the lower 2 bits of PORT 2. The single-step feature simplifies program debugging by allowing the user to easily follow program execution.

Figure 4-1 illustrates a recommended circuit for single-step operation, while Figure 4-2 shows the timing relationship between the SYNC output and the $\overline{SS}$ input. During single-step operation, PORT 1 and part of PORT 2 are used to output address information. In order to retain the normal I/O functions of PORTS 1 and 2, a separate latch can be used as shown in Figure 4-3.

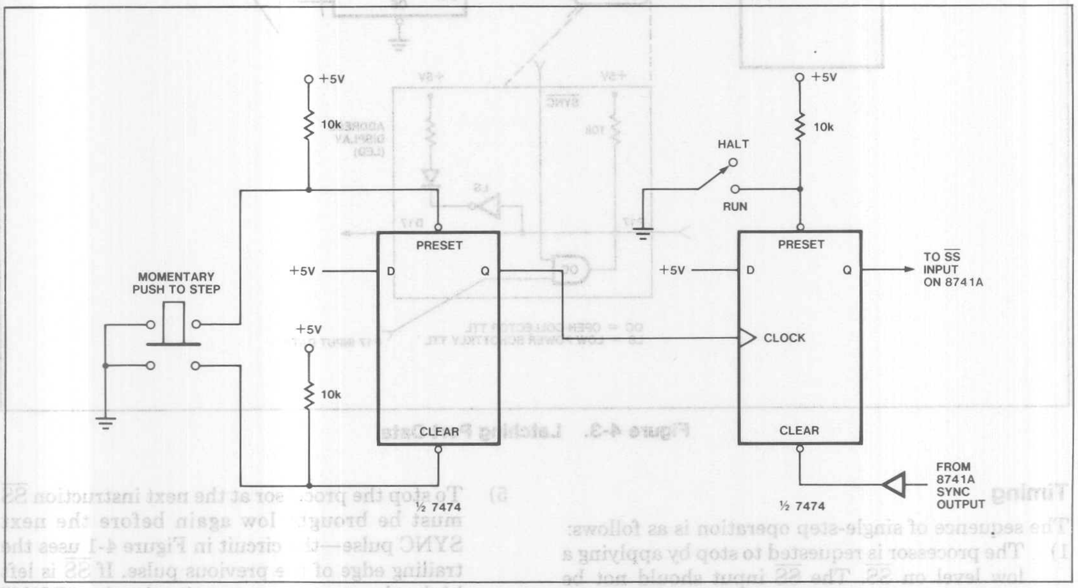


Figure 4-1. Single-Step Circuit

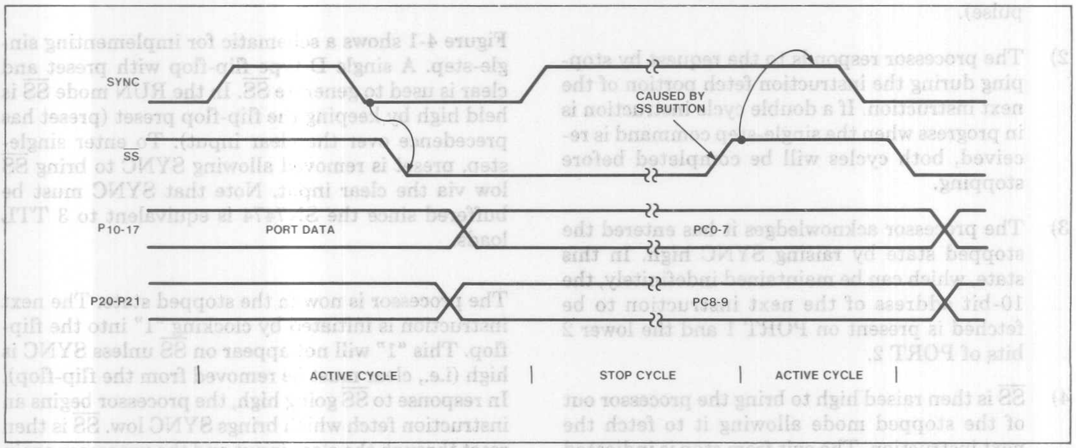


Figure 4-2. Single-Step Timing

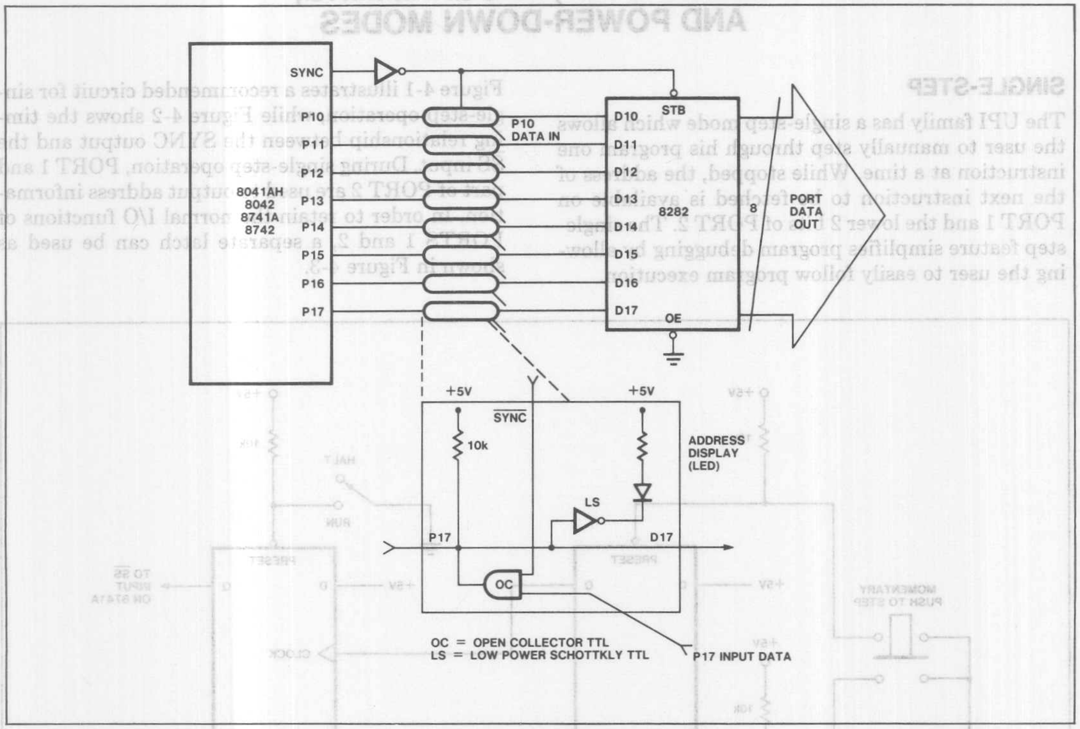


Figure 4-3. Latching Port Data

Timing

The sequence of single-step operation is as follows:

1) The processor is requested to stop by applying a low level on $\overline{SS}$. The $\overline{SS}$ input should not be brought low while SYNC is high. (The UPI samples the $\overline{SS}$ pin in the middle of the SYNC pulse).

2) The processor responds to the request by stopping during the instruction fetch portion of the next instruction. If a double cycle instruction is in progress when the single-step command is received, both cycles will be completed before stopping.

3) The processor acknowledges it has entered the stopped state by raising SYNC high. In this state, which can be maintained indefinitely, the 10-bit address of the next instruction to be fetched is present on PORT 1 and the lower 2 bits of PORT 2.

4) $\overline{SS}$ is then raised high to bring the processor out of the stopped mode allowing it to fetch the next instruction. The exit from stop is indicated by the processor bringing SYNC low.

5) To stop the processor at the next instruction $\overline{SS}$ must be brought low again before the next SYNC pulse—the circuit in Figure 4-1 uses the trailing edge of the previous pulse. If $\overline{SS}$ is left high, the processor remains in the "RUN" mode.

Figure 4-1 shows a schematic for implementing single-step. A single D-type flip-flop with preset and clear is used to generate $\overline{SS}$. In the RUN mode $\overline{SS}$ is held high by keeping the flip-flop preset (preset has precedence over the clear input). To enter single-step, preset is removed allowing SYNC to bring $\overline{SS}$ low via the clear input. Note that SYNC must be buffered since the SN7474 is equivalent to 3 TTL loads.

The processor is now in the stopped state. The next instruction is initiated by clocking "1" into the flip-flop. This "1" will not appear on $\overline{SS}$ unless SYNC is high (i.e., clear must be removed from the flip-flop). In response to $\overline{SS}$ going high, the processor begins an instruction fetch which brings SYNC low. $\overline{SS}$ is then reset through the clear input and the processor again enters the stopped state.

PROGRAMMING, VERIFYING AND ERASING EPROM (8741A, 8742 EPROM ONLY)

The internal Program Memory of the 8741A and 8742 may be erased and reprogrammed by the user as explained in the following sections. See the data sheet for more detail.

Programming

The programming procedure consists of the following: activating the program mode, applying an address, latching the address, applying data, and applying a programming pulse. Each word is programmed completely before moving on to the next and is followed by a verification step. Figure 4-4 illustrates the programming and verifying sequence. The following is a list of the pins used for programming and a description of their functions:

- XTAL 1, XTAL 2 — Clock Input
- $\overline{RESET}$ — Initialization and Address Latching
- TEST 0 — Selection of Program or Verify Mode
- EA — Activation of Program/Verify Modes
- D_0–D_7 — Address and Data Input; Data Output During Verify
- P_{20}, P_{21} — Address Input
- V_{DD} — Programming Power Supply
- PROG — Program Pulse Input

NOTE: All set-up and hold times are 4 cycles.

The detailed Programming sequence (for one byte) is as follows:

1) Initial Conditions: $V_{CC} = V_{DD} = 5V$; Clock Running; $A_0 = 0V$, $\overline{CS} = 5V$; $EA = 5V$; D_0–D_7 and PROG Floating.

2) $\overline{RESET} = 0V$, TEST 0 = 0V (Select Programming Mode).

3) EA = 23V for 8741A
EA = 18V for 8742

4) Address applied to D_0–D_7 and PORTS 20–22.

5) $\overline{RESET} = 5V$ (Latch Address).

6) Data applied to D_0–D_7.

7) $V_{DD} = 25V$ for 8741A
$V_{DD} = 21V$ for 8742 (Programming Power).

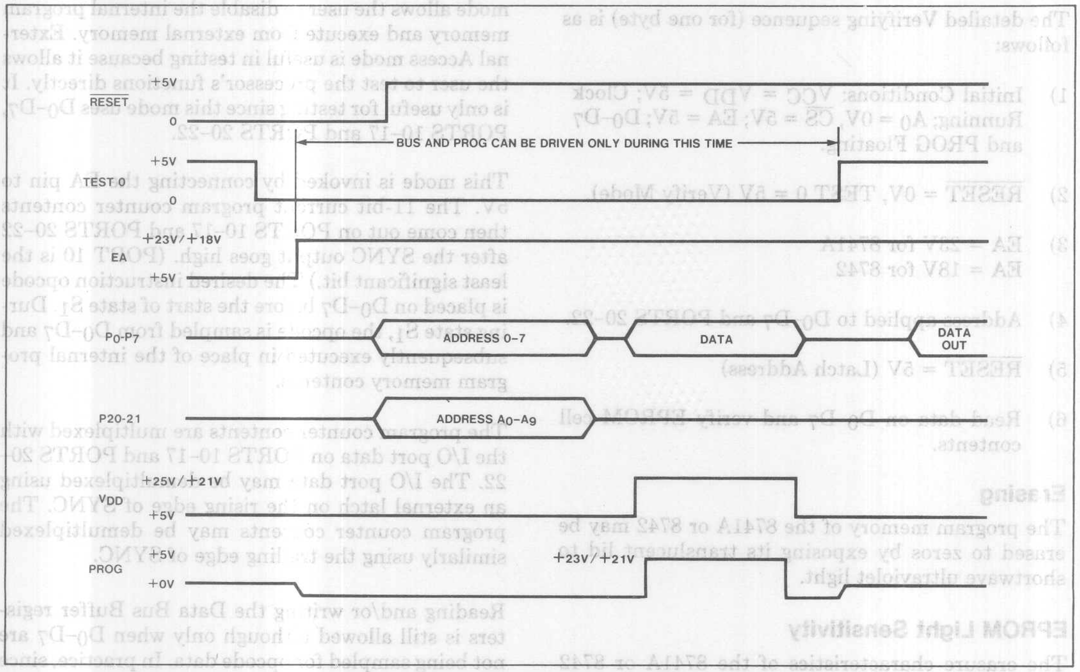


Figure 4-4. Programming Sequence

8) PROG = 0V followed by one 50 msec pulse of 23V for 8741A
PROG = 0V followed by one 50 msec pulse of 18V for 8742.

9) V_{DD} = 5V.

10) TEST 0 = 5V (Select Verify Mode).

11) Read data on D_0–D_7 and verify EPROM cell contents.

WARNING

An attempt to program a mis-socketed 8741A or 8742 will result in severe damage to the part. An indication of a properly socketed part is the appearance of the SYNC clock output. The lack of this clock may be used to disable the programmer.

Verification

Verification is accomplished by latching in an address as in the Programming Mode and then applying "1" to the TEST 0 input. The word stored at the selected address then appears on the D_0–D_7 lines. Note that verification can be applied to both ROM's and EPROM's independently of the programming procedure. See the data sheet.

The detailed Verifying sequence (for one byte) is as follows:

1) Initial Conditions: $V_{CC} = V_{DD}$ = 5V; Clock Running; A_0 = 0V, $\overline{CS}$ = 5V; EA = 5V; D_0–D_7 and PROG Floating.

2) $\overline{RESET}$ = 0V, TEST 0 = 5V (Verify Mode).

3) EA = 23V for 8741A
EA = 18V for 8742

4) Address applied to D_0–D_7 and PORTS 20–22.

5) $\overline{RESET}$ = 5V (Latch Address)

6) Read data on D_0–D_7 and verify EPROM cell contents.

Erasing

The program memory of the 8741A or 8742 may be erased to zeros by exposing its translucent lid to shortwave ultraviolet light.

EPROM Light Sensitivity

The erasure characteristics of the 8741A or 8742 EPROM are such that erasure begins to occur when exposed to light with wavelengths shorter than approximately 4000 Angstroms. It should be noted that sunlight and certain types of fluorescent lamps have wavelengths in the 3000–4000 Angstrom range. Data shows that constant exposure to room level fluorescent lighting could erase the typical 8741A in approximately 3 years while it would take approximately 1 week to cause erasure when exposed to direct sunlight. If the 8741A or 8742 is to be exposed to these types of lighting conditions for extended periods of time, opaque labels (available from Intel) should be placed over the 8741A or 8742 window to prevent unintentional erasure.

The recommended erasure procedure for the 8741A or 8742 is exposure to shortwave ultraviolet light which has a wavelength of 2537 Angstroms. The integrated dose (i.e., UV intensity × exposure time) for erasure should be a minimum of 15W-sec/cm^2 power rating. The erasure time with this dosage is approximately 15 minutes using an ultraviolet lamp with a 12,000 μW/cm^2 power rating. The 8741A or 8742 should be placed within 1 inch of the lamp tubes during erasure. Some lamps have a filter on their tubes which should be removed before erasure.

EXTERNAL ACCESS

The UPI family has an External Access mode (EA) which puts the processor into a test mode. This mode allows the user to disable the internal program memory and execute from external memory. External Access mode is useful in testing because it allows the user to test the processor's functions directly. It is only useful for testing since this mode uses D_0–D_7, PORTS 10–17 and PORTS 20–22.

This mode is invoked by connecting the EA pin to 5V. The 11-bit current program counter contents then come out on PORTS 10–17 and PORTS 20–22 after the SYNC output goes high. (PORT 10 is the least significant bit.) The desired instruction opcode is placed on D_0–D_7 before the start of state S_1. During state S_1, the opcode is sampled from D_0–D_7 and subsequently executed in place of the internal program memory contents.

The program counter contents are multiplexed with the I/O port data on PORTS 10–17 and PORTS 20–22. The I/O port data may be demultiplexed using an external latch on the rising edge of SYNC. The program counter contents may be demultiplexed similarly using the trailing edge of SYNC.

Reading and/or writing the Data Bus Buffer registers is still allowed although only when D_0–D_7 are not being sampled for opcode data. In practice, since this sampling time is not known externally, reads or

writes on the system bus are done during SYNC high time. Approximately 600ns are available for each read or write cycle.

POWER DOWN MODE (8041AH/8042 ROM ONLY)

Extra circuitry is included in the ROM version to allow low-power, standby operation. Power is removed from all system elements except the internal data RAM in the low-power mode. Thus the contents of RAM can be maintained and the device draws only 10 to 15% of its normal power.

The V_{CC} pin serves as the 5V power supply pin for all of the ROM version's circuitry except the data RAM array. The V_{DD} pin supplies only the RAM array. In normal operation, both V_{CC} and V_{DD} are connected to the same 5V power supply.

To enter the Power-Down mode, the $\overline{\text{RESET}}$ signal to the UPI is asserted. This ensures the memory will not be inadvertently altered by the UPI during power-down. The V_{CC} pin is then grounded while V_{DD} is maintained at 5V. Figure 4-5 illustrates a recommended Power-Down sequence. The sequence typically occurs as follows:

1) Imminent power supply failure is detected by user defined circuitry. The signal must occur early enough to guarantee the 8041AH or 8042 can save all necessary data before V_{CC} falls outside normal operating tolerance.

2) A "Power Failure" signal is used to interrupt the processor (via a timer overflow interrupt, for instance) and call a Power Failure service routine.

3) The Power Failure routine saves all important data and machine status in the RAM array. The routine may also initiate transfer of a backup supply to the V_{DD} pin and indicate to external circuitry that the Power Failure routine is complete.

4) A $\overline{\text{RESET}}$ signal is applied by external hardware to guarantee data will not be altered as the power supply falls out of limits. $\overline{\text{RESET}}$ must be low until V_{CC} reaches ground potential.

Recovery from the Power-Down mode can occur as any other power-on sequence. An external 1 μfd capacitor on the $\overline{\text{RESET}}$ input will provide the necessary initialization pulse.

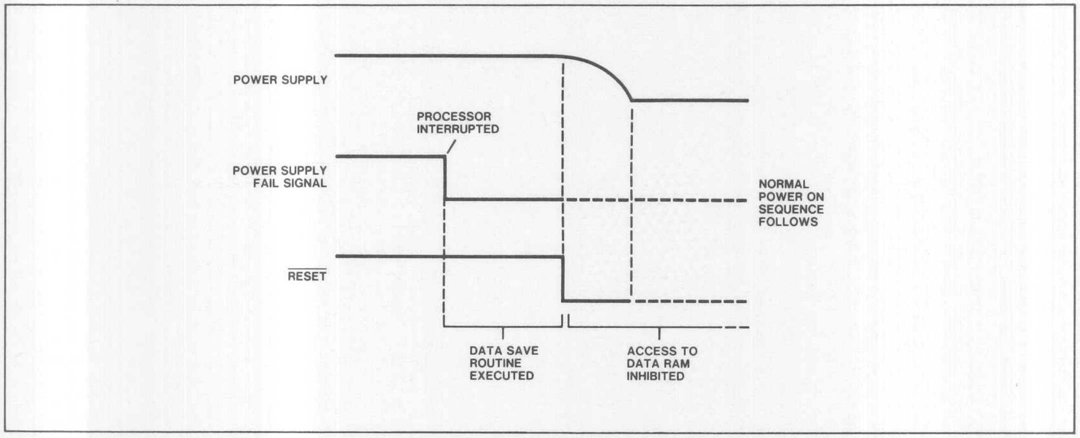


Figure 4-5. Power-Down Sequence

System Operation 5

CHAPTER 5
SYSTEM OPERATION

BUS INTERFACE

The UPI-41AH, 42 Microcomputer functions as a peripheral to a master processor by using the data bus buffer registers to handle data transfers. The DBB configuration is illustrated in Figure 5-1. The UPI-41AH, 42 Microcomputer's 8 three-state data lines (D_7–D_0) connect directly to the master processor's data bus. Data transfer to the master is controlled by 4 external inputs to the UPI:

- A_0 Address Input signifying command or data
- $\overline{CS}$ Chip Select
- $\overline{RD}$ Read strobe
- $\overline{WR}$ Write strobe

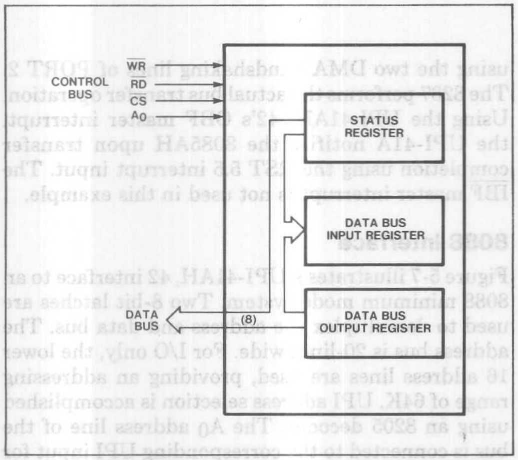


Figure 5-1. Data Bus Register Configuration

The master processor addresses the UPI-41AH, 42 Microcomputer as a standard peripheral device. Table 5-1 shows the conditions for data transfer:

Table 5-1. Data Transfer Controls

$\overline{CS}$	A_0	$\overline{RD}$	$\overline{WR}$	Condition
0	0	0	1	Read DBBOUT
0	1	0	1	Read STATUS
0	0	1	0	Write DBBIN data, set $F_1 = 0$
0	1	1	0	Write DBBIN command set $F_1 = 1$
1	x	x	x	Disable DBB

Reading the DBBOUT Register

The sequence for reading the DBBOUT register is shown in Figure 5-2. This operation causes the 8-bit contents of the DBBOUT register to be placed on the system Data Bus. The OBF flag is cleared automatically.

Reading STATUS

The sequence for reading the UPI-41AH, 42 Microcomputer's 8 STATUS bits is shown in Figure 5-3. This operation causes the 8-bit STATUS register contents to be placed on the system Data Bus as shown.

Write Data to DBBIN

The sequence for writing data to the DBBIN register is shown in Figure 5-4. This operation causes the system Data Bus contents to be transferred to the DBBIN register and the IBF flag is set. Also, the F_1 flag is cleared ($F_1 = 0$) and an interrupt request is generated. When the IBF interrupt is enabled, a jump to location 3 will occur. The interrupt request is cleared upon entering the IBF service routine or by a system RESET input.

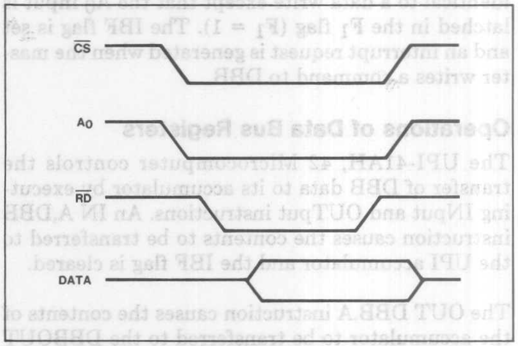


Figure 5-2. DBBOUT Read

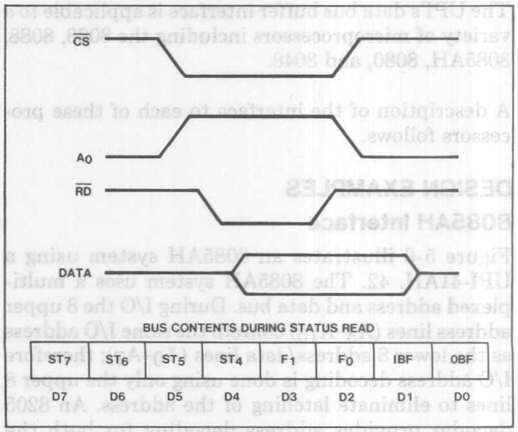


Figure 5-3. Status Read

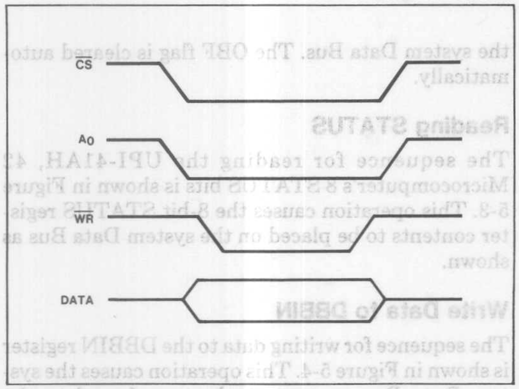


Figure 5-4. Writing Data to DBBIN

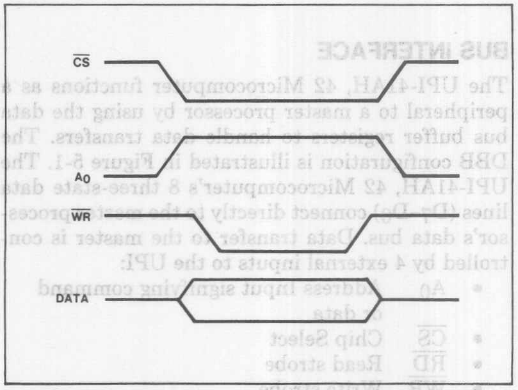


Figure 5-5. Writing Commands to DBBIN

Writing Commands to DBBIN

The sequence for writing commands to the DBBIN register is shown in Figure 5-5. This sequence is identical to a data write except that the A_0 input is latched in the F_1 flag ($F_1 = 1$). The IBF flag is set and an interrupt request is generated when the master writes a command to DBB.

Operations of Data Bus Registers

The UPI-41AH, 42 Microcomputer controls the transfer of DBB data to its accumulator by executing INput and OUTput instructions. An IN A,DBB instruction causes the contents to be transferred to the UPI accumulator and the IBF flag is cleared.

The OUT DBB,A instruction causes the contents of the accumulator to be transferred to the DBBOUT register. The OBF flag is set.

The UPI's data bus buffer interface is applicable to a variety of microprocessors including the 8086, 8088, 8085AH, 8080, and 8048.

A description of the interface to each of these processors follows.

DESIGN EXAMPLES

8085AH Interface

Figure 5-6 illustrates an 8085AH system using a UPI-41AH, 42. The 8085AH system uses a multiplexed address and data bus. During I/O the 8 upper address lines (A_8–A_{15}) contain the same I/O address as the lower 8 address/data lines (A_0–A_7); therefore I/O address decoding is done using only the upper 8 lines to eliminate latching of the address. An 8205 decoder provides address decoding for both the UPI-41AH, 42 and the 8237. Data is transferred using the two DMA handshaking lines of PORT 2. The 8237 performs the actual bus transfer operation. Using the UPI-41AH, 42's OBF master interrupt, the UPI-41A notifies the 8085AH upon transfer completion using the RST 5.5 interrupt input. The $\overline{\text{IBF}}$ master interrupt is not used in this example.

8088 Interface

Figure 5-7 illustrates a UPI-41AH, 42 interface to an 8088 minimum mode system. Two 8-bit latches are used to demultiplex the address and data bus. The address bus is 20-lines wide. For I/O only, the lower 16 address lines are used, providing an addressing range of 64K. UPI address selection is accomplished using an 8205 decoder. The A_0 address line of the bus is connected to the corresponding UPI input for register selection. Since the UPI-41A is polled by the 8088, neither DMA nor master interrupt capabilities of the UPI-41AH, 42 are used in the figure.

8086 Interface

The UPI-41AH, 42 can be used on an 8086 maximum mode system as shown in figure 5-8. The address and data bus is demultiplexed using three 8282 latches providing separate address and data buses. The address bus is 20-lines wide and the data bus is 16-lines wide. Multiplexed control lines are decoded by the 8288. The UPI's $\overline{\text{CS}}$ input is provided by linear selection. Note that the UPI-41AH, 42 is both I/O mapped and memory mapped as a result of the linear addressing technique. An address decoder may be used to limit the UPI-41AH, 42 to a specific I/O mapped address. Address line A_1 is connected to the UPI's A_0 input. This insures that the registers of the UPI will have even I/O addresses. Data will be transferred on D_0–D_7 lines only. This allows the I/O registers to be accessed using byte manipulation instructions.

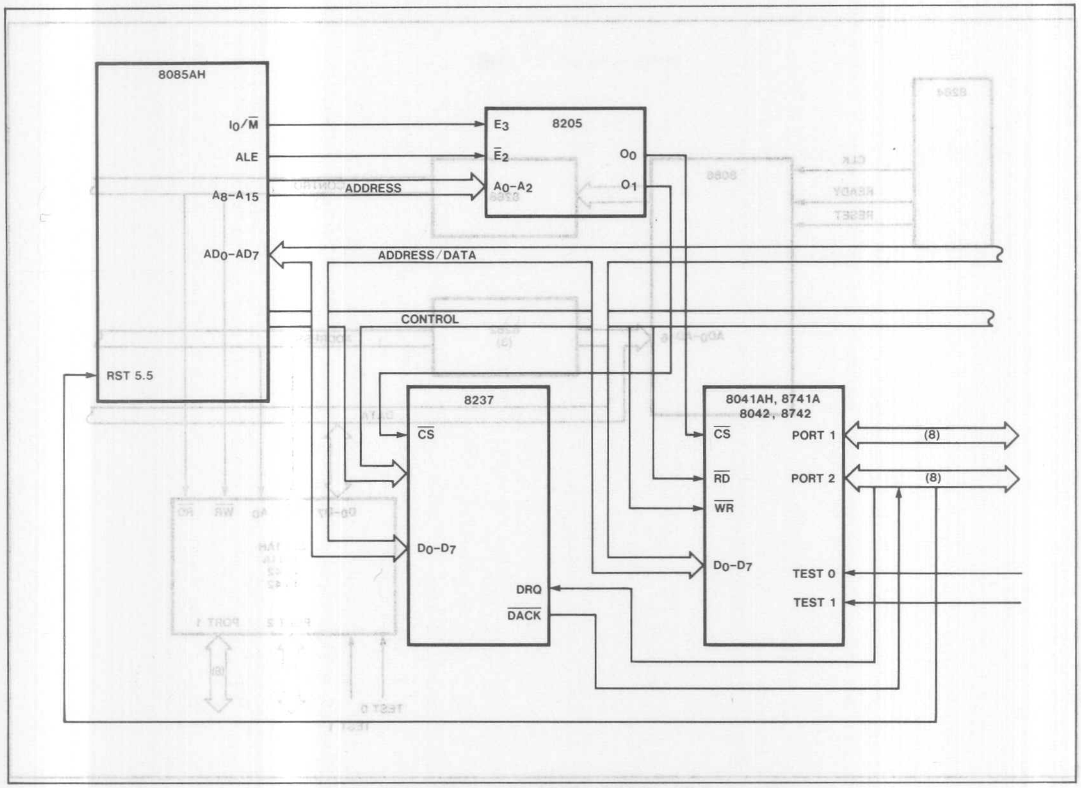


Figure 5-6. 8085AH-UPI System

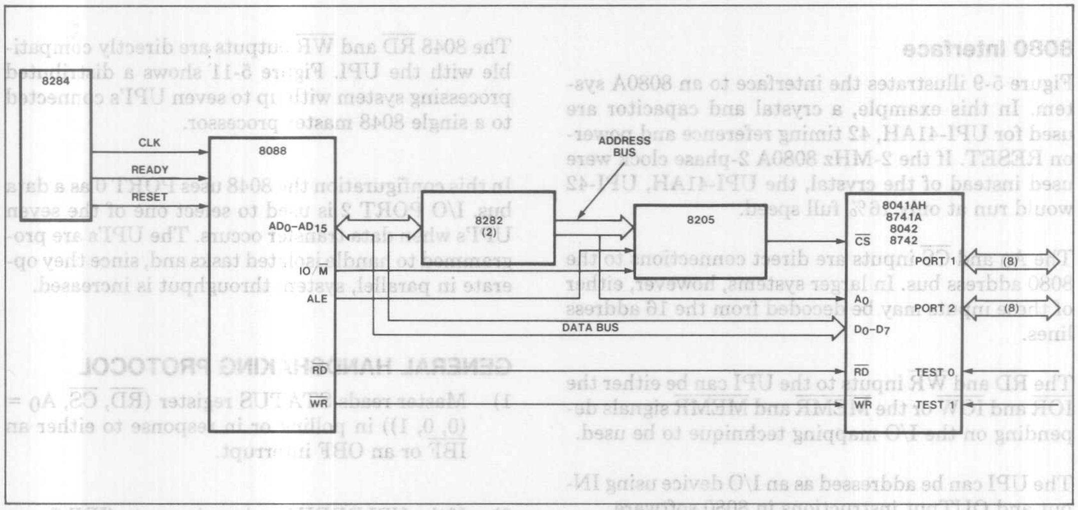


Figure 5-7. 8088-UPI Minimum Mode System

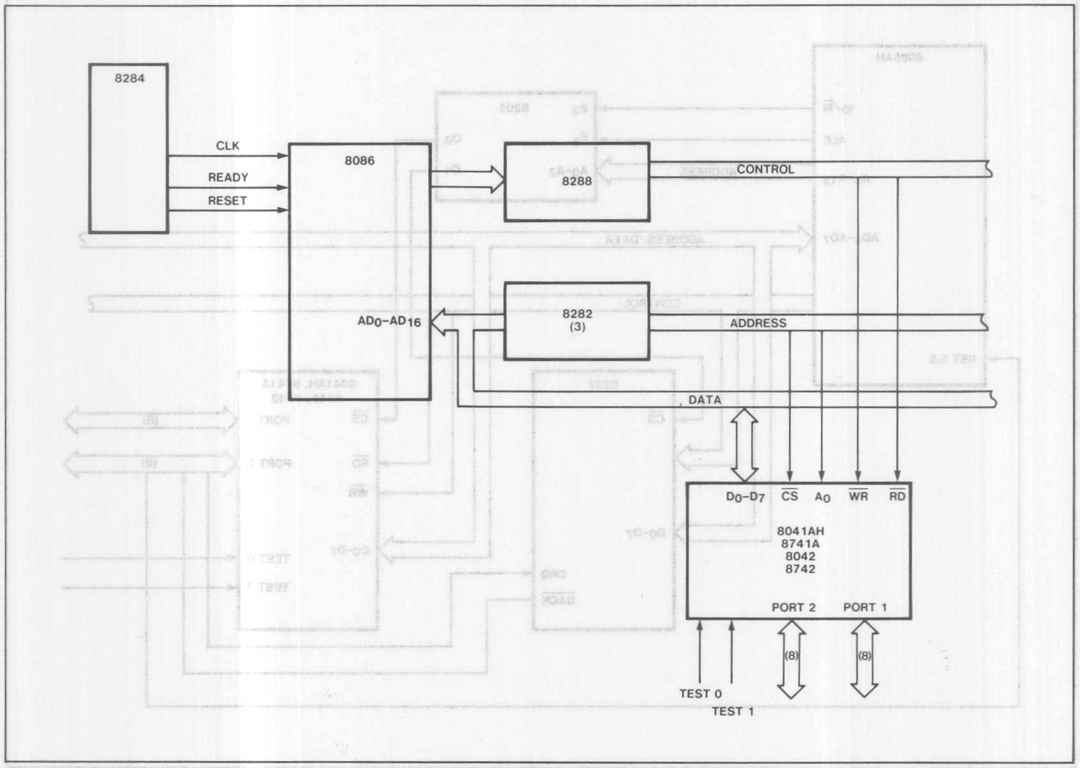


Figure 5-8. 8086-UPI Maximum Mode Systems

8080 Interface

Figure 5-9 illustrates the interface to an 8080A system. In this example, a crystal and capacitor are used for UPI-41AH, 42 timing reference and power-on RESET. If the 2-MHz 8080A 2-phase clock were used instead of the crystal, the UPI-41AH, UPI-42 would run at only 16% full speed.

The A_0 and $\overline{CS}$ inputs are direct connections to the 8080 address bus. In larger systems, however, either of these inputs may be decoded from the 16 address lines.

The $\overline{RD}$ and $\overline{WR}$ inputs to the UPI can be either the $\overline{IOR}$ and $\overline{IOW}$ or the $\overline{MEMR}$ and $\overline{MEMR}$ signals depending on the I/O mapping technique to be used.

The UPI can be addressed as an I/O device using INput and OUTput instructions in 8080 software.

8048 Interface

Figure 5-10 shows the UPI interface to an 8048 master processor.

The 8048 $\overline{RD}$ and $\overline{WR}$ outputs are directly compatible with the UPI. Figure 5-11 shows a distributed processing system with up to seven UPI's connected to a single 8048 master processor.

In this configuration the 8048 uses PORT 0 as a data bus. I/O PORT 2 is used to select one of the seven UPI's when data transfer occurs. The UPI's are programmed to handle isolated tasks and, since they operate in parallel, system throughput is increased.

GENERAL HANDSHAKING PROTOCOL

1) Master reads STATUS register ($\overline{RD}$, $\overline{CS}$, A_0 = (0, 0, 1)) in polling or in response to either an IBF or an OBF interrupt.

2) If the UPI DBBIN register is empty (IBF flag = 0), Master writes a word to the DBBIN register ($\overline{WR}$, $\overline{CS}$, A_0 = (0, 0, 1) or (0, 0, 0)). If A_0 = 1, write command word, set F_1. If A_0 = 0, write data word, F_1 = 0.

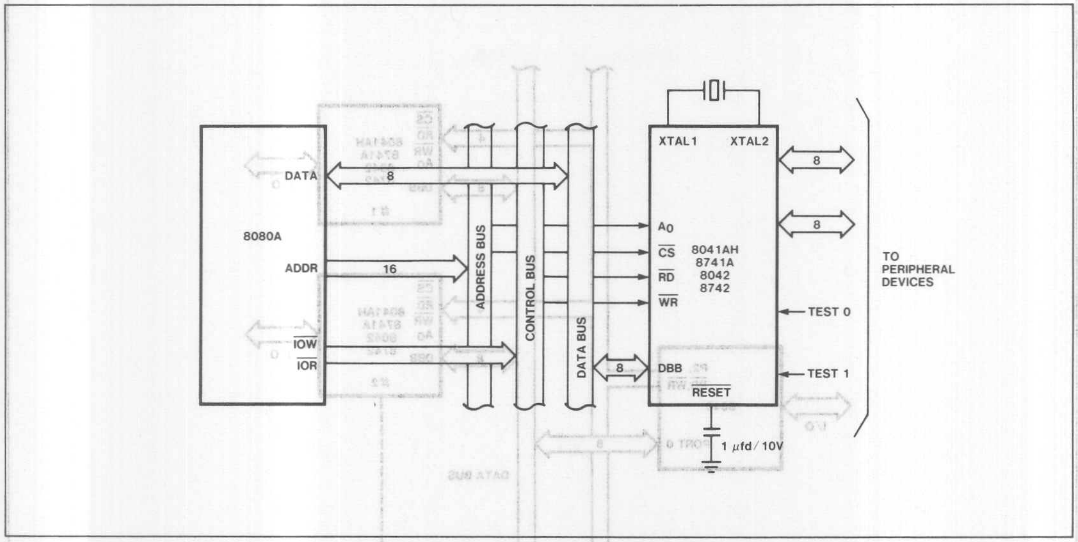


Figure 5-9. 8080A-UPI Interface

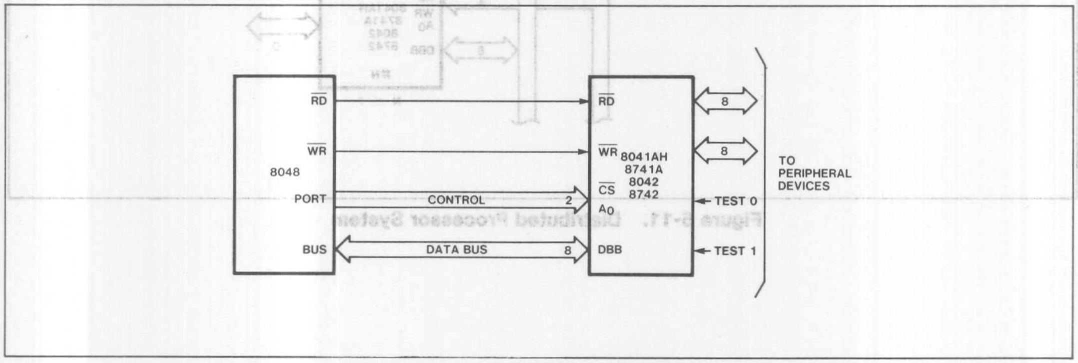


Figure 5-10. 8048-UPI Interface

3) If the UPI DBBOUT register is full (OBF flag = 1), Master reads a word from the DBBOUT register ($\overline{RD}$, $\overline{CS}$, A_0 = (0, 0, 0)).

4) UPI recognizes IBF (via IBF interrupt or JNIBF). Input data or command word is processed, depending on F_1; IBF is reset. Repeat step 1 above.

5) UPI-41AH, 42 recognizes OBF flag = 0 (via JOBF). Next word is output to DBBOUT register, OBF is set. Repeat step 1 above.

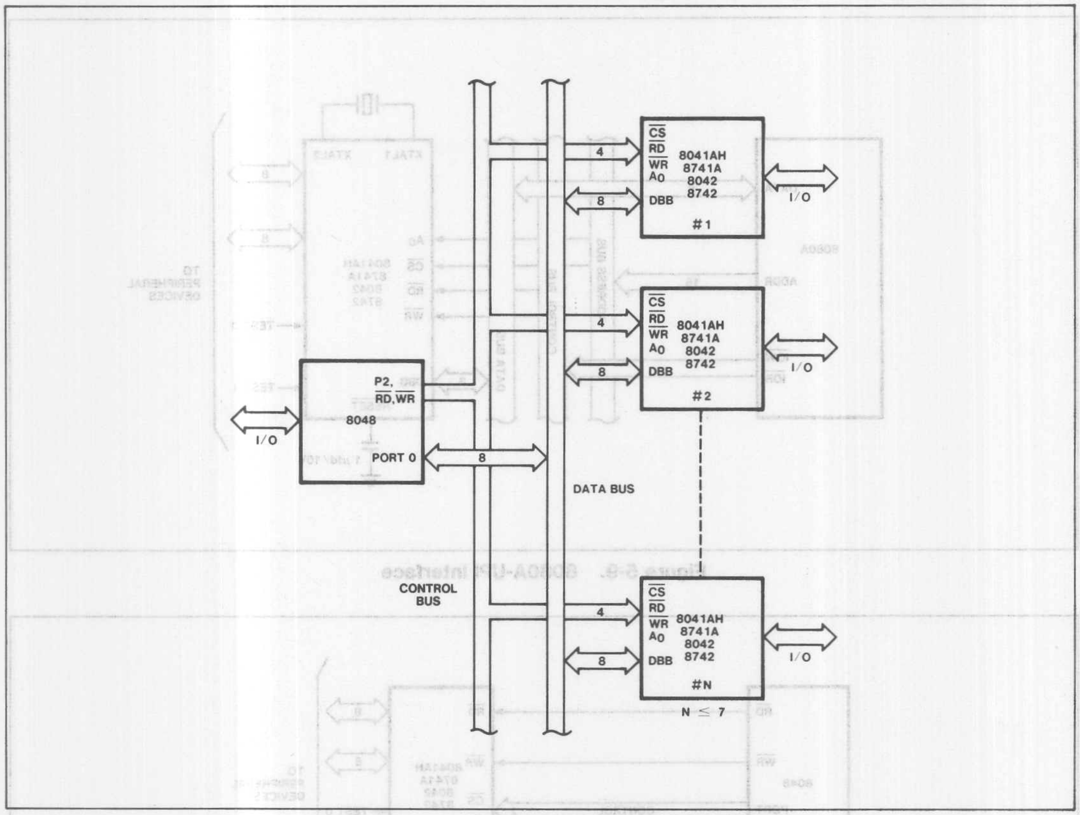


Figure 5-11. Distributed Processor System

Applications 6

Chapter 6
APPLICATIONS

ABSTRACTS

The UPI-41A is designed to fill a wide variety of low to medium speed peripheral interface applications where flexibility and easy implementation are important considerations. The following examples illustrate some typical applications.

Keyboard Encoder

Figure 6-1 illustrates a keyboard encoder configuration using the UPI and the 8243 I/O expander to scan a 128-key matrix. The encoder has switch matrix scanning logic, N-key rollover logic, ROM look-up table, FIFO character buffer, and additional outputs for display functions, control keys or other special functions.

PORT 1 and PORTs 4–7 provide the interface to the keyboard. PORT 1 lines are set one at a time to select the various key matrix rows.

When a row is energized, all 16 columns (i.e., PORTs 4–7 inputs) are sampled to determine if any switch in the row is closed. The scanning software is code efficient because the UPI instruction set includes individual bit set/clear operations and expander PORTs 4–7 can be directly addressed with single, 2-byte instructions. Also, accumulator bits can be tested in a single operation. Scan time for 128 keys is about 10 ms. Each matrix point has a unique binary code which is used to address ROM when a key closure is detected. Page 3 of ROM contains a look-up table with useable codes (i.e., ASCII, EBCDIC, etc.) which correspond to each key. When a valid key closure is detected the ROM code corresponding to that key is stored in a FIFO buffer in data memory for transfer to the master processor. To avoid stray noise and switch bounce, a key closure must be detected on two consecutive scans before it is considered valid and loaded into the FIFO buffer. The FIFO buffer allows multiple keys to be processed as they are depressed without regard to when they are released, a condition known as N-key rollover.

The basic features of this encoder are fairly standard and require only about 500 bytes of memory. Since the UPI is programmable and has additional memory capacity it can handle a number of other functions. For example, special keys can be programmed to give an entry on closing as well as opening. Also, I/O lines are available to control a 16-digit, 7-segment display. The UPI can also be programmed to recognize special combinations of characters such as commands, then transfer only the decoded information to the master processor.

A complete keyboard application has been developed for the UPI-41A. A description is included in this section. The code for the application is available in the Intel Insite Library (program AB 147).

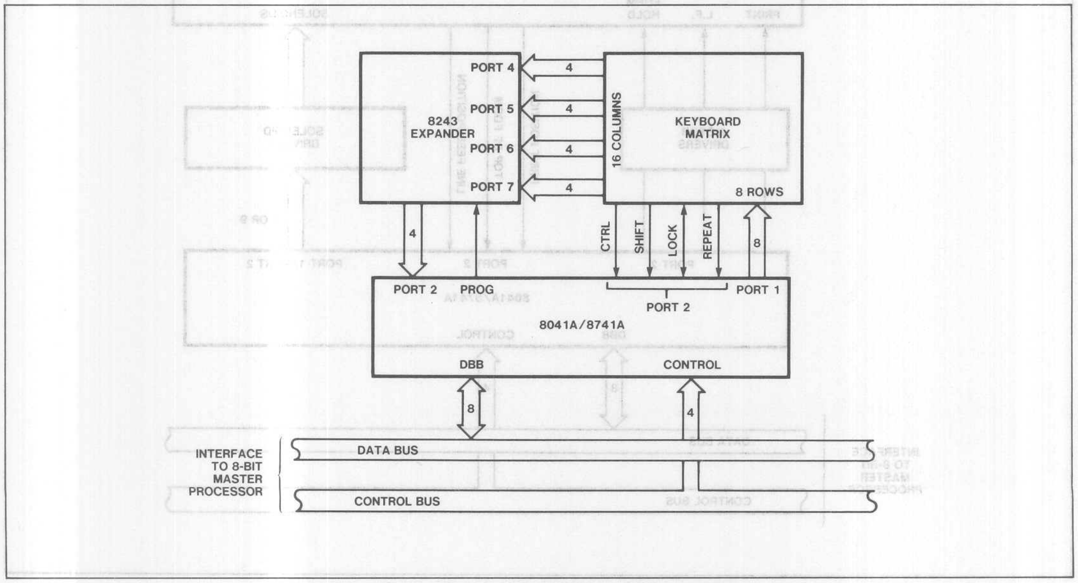


Figure 6-1. Keyboard Encoder Configuration

Matrix Printer Interface

The matrix printer interface illustrated in Figure 6-2 is a typical application for the UPI-41A. The actual printer mechanism could be any of the numerous dot-matrix types and similar configurations can be shown for drum, spherical head, daisy wheel or chain type printers.

The bus structure shown represents a generalized, 8-bit system bus configuration. The UPI's three-state interface port and asynchronous data buffer registers allow it to connect directly to this type of system for efficient, two-way data transfer.

The UPI's two on-board I/O ports provide up to 16 input and output signals to control the printer mechanism. The timer/event counter is used for generating a timing sequence to control print head position, line feed, carriage return, and other sequences. The on-board program memory provides character generation for 5×7, 7×9, or other dot matrix formats. As an added feature a portion of the 64×8-bit data memory can be used as a FIFO buffer so that the master processor can send a block of data at a high rate. The UPI can then output characters from the buffer at a rate the printer can accept while the master processor returns to other tasks.

The 8295 Printer Controller is an example of an 8041A preprogrammed as a dot matrix printer interface.

Tape Cassette Controller

Figure 6-3 illustrates a digital cassette interface which can be implemented with the UPI-41A. Two sections of the tape transport are controlled by the UPI: digital data/command logic, and motor servo control.

The motor servo requires a speed reference in the form of a monostable pulse whose width is proportional to the desired speed. The UPI monitors a prerecorded clock from the tape and uses its on-board interval timer to generate the required speed reference pulses at each clock transition.

Recorded data from the tape is supplied serially by the data/command logic and is converted to 8-bit words by the UPI, then transferred to the master processor. At 10 ips tape speed the UPI can easily handle the 8000 bps data rate. To record data, the UPI uses the two input lines to the data/command logic which control the flux direction in the recording head. The UPI also monitors 4 status lines from the tape transport including: end of tape, cassette

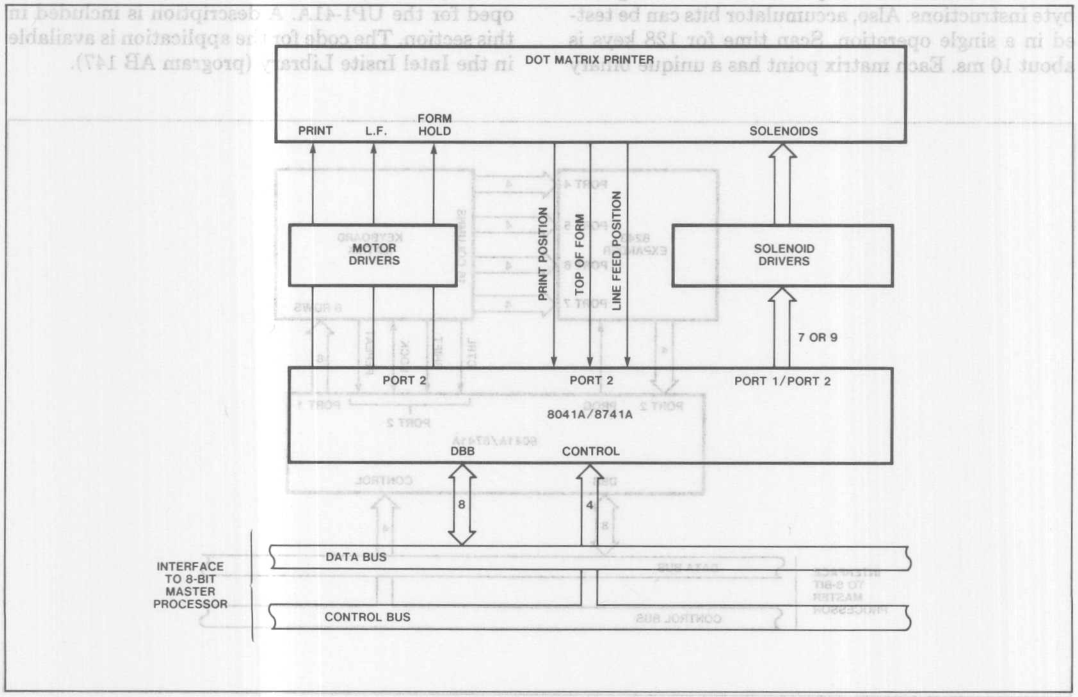


Figure 6-2. Matrix Printer Controller

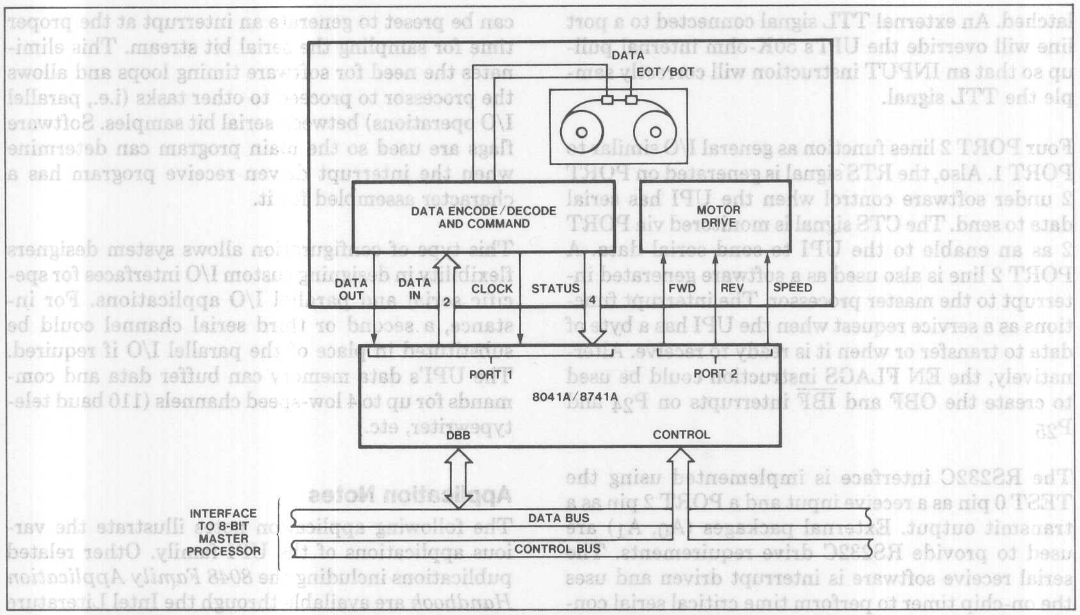


Figure 6-3. Tape Transport Controller

inserted, busy, and write permit. All control signals can be handled by the UPI's two I/O ports.

Universal I/O Interface

Figure 6-4 shows an I/O interface design based on the UPI. This configuration includes 12 parallel I/O lines and a serial (RS232C) interface for full duplex data transfer up to 1200 baud. This type of design can be used to interface a master processor to a broad spectrum of peripheral devices as well as to a serial communication channel.

PORT 1 is used strictly for I/O in this example while PORT 2 lines provide five functions:

- P_{23}-P_{20} I/O lines (bidirectional)
- P_{24} Request to send (RTS)
- P_{25} Clear to Send (CTS)
- P_{26} Interrupt to master
- P_{27} Serial data out

The parallel I/O lines make use of the bidirectional port structure of the UPI. Any line can function as an input or output. All port lines are automatically initialized to 1 by a system $\overline{\text{RESET}}$ pulse and remain

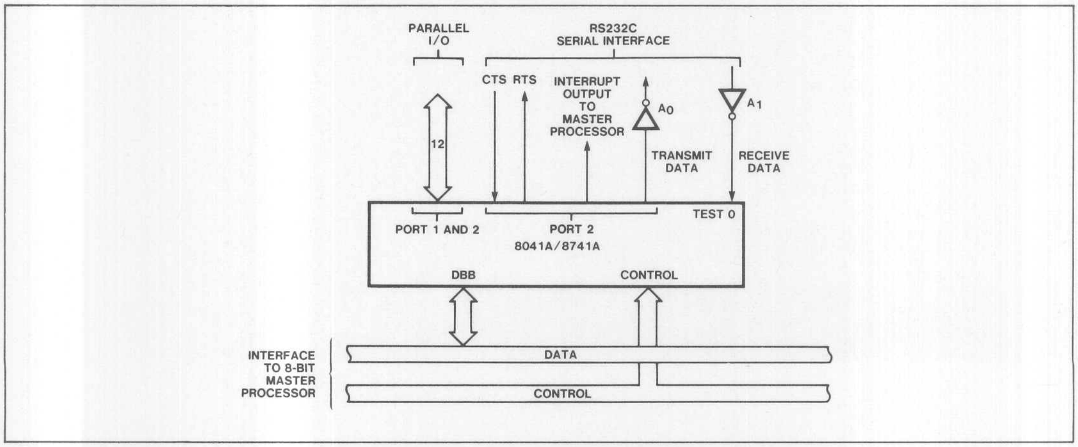


Figure 6-4. Universal I/O Interface

latched. An external TTL signal connected to a port line will override the UPI's 50K-ohm internal pull-up so that an INPUT instruction will correctly sample the TTL signal.

Four PORT 2 lines function as general I/O similar to PORT 1. Also, the RTS signal is generated on PORT 2 under software control when the UPI has serial data to send. The CTS signal is monitored via PORT 2 as an enable to the UPI to send serial data. A PORT 2 line is also used as a software generated interrupt to the master processor. The interrupt functions as a service request when the UPI has a byte of data to transfer or when it is ready to receive. Alternatively, the EN FLAGS instruction could be used to create the OBF and $\overline{\text{IBF}}$ interrupts on P_{24} and P_{25}.

The RS232C interface is implemented using the TEST 0 pin as a receive input and a PORT 2 pin as a transmit output. External packages (A_0, A_1) are used to provide RS232C drive requirements. The serial receive software is interrupt driven and uses the on-chip timer to perform time critical serial control. After a start bit is detected the interval timer can be preset to generate an interrupt at the proper time for sampling the serial bit stream. This eliminates the need for software timing loops and allows the processor to proceed to other tasks (i.e., parallel I/O operations) between serial bit samples. Software flags are used so the main program can determine when the interrupt driven receive program has a character assembled for it.

This type of configuration allows system designers flexibility in designing custom I/O interfaces for specific serial and parallel I/O applications. For instance, a second or third serial channel could be substituted in place of the parallel I/O if required. The UPI's data memory can buffer data and commands for up to 4 low-speed channels (110 baud teletypewriter, etc.)

Application Notes

The following application notes illustrate the various applications of the UPI family. Other related publications including the *8048 Family Application Handbook* are available through the Intel Literature Department.

INTRODUCTION TO THE UPI-41A™

Introduction

Since the introduction in 1974 of the second generation of microprocessors, such as the 8080, a wide range of peripheral interface devices have appeared. At first, these devices solved application problems of a general nature; i.e., parallel interface (8255), serial interface (8251), timing (8253), interrupt control (8259). However, as the speed and density of LSI technology increased, more and more intelligence was incorporated into the peripheral devices. This allowed more specific application problems to be solved, such as floppy disk control (8271), CRT control (8275), and data link control (8273). The advantage to the system designer of this increased peripheral device intelligence is that many of the peripheral control tasks are now handled externally to the main processor in the peripheral hardware rather than internally in the main processor software. This reduced main processor overhead results in increased system throughput and reduced software complexity.

In spite of the number of peripheral devices available, the pervasiveness of the microprocessor has been such that there is still a large number of peripheral control applications not yet satisfied by dedicated LSI. Complicating this problem is the fact that new applications are emerging faster than the manufacturers can react in developing new, dedicated peripheral controllers. To address this problem, a new microcomputer-based Universal Peripheral Interface (UPI-41A) device was developed.

In essence, the UPI-41A acts as a slave processor to the main system CPU. The UPI contains its own processor, memory, and I/O, and is completely user programmable; that is, the entire peripheral control algorithm can be programmed locally in the UPI, instead of taxing the master processor's main memory. This distributed processing concept allows the UPI to handle the real-time tasks such as encoding keyboards, controlling printers, or multiplexing displays, while the main processor is handling non-real-time dependent tasks such as buffer management or arithmetic. The UPI relies on the master only for initialization, elementary commands, and data transfers. This technique results in an overall increase in system efficiency since both processors—the master CPU and the slave UPI—are working in parallel.

This application note presents three UPI-41A applications which are roughly divided into two groups: applications whose complexity and UPI code space requirements allow them to either stand alone or be incorporated as just one task in a "multi-tasking" UPI, and applications which are complete UPI applications in themselves. Applications in the first group are a simple LED display and sensor matrix controllers. A combination serial/parallel/ I/O device is an application in the second group. Each application illustrates different UPI configurations and features. However, before the application details are presented, a section on the UPI/master protocol requirements is included. These protocol requirements are key to UPI software development. For convenience, the UPI block diagram is reproduced in Figure 1 and the instruction set summary in Table 1.

UPI-41 vs. UPI-41A

The UPI-41A is an enhanced version of the UPI-41. It incorporates several architectural features not found on the "non-A" device:

- Separate Data In and Data Out data bus buffer registers
- User-definable STATUS register bits
- Programmable master interrupts for the OBF and $\overline{\text{IBF}}$ flags
- Programmable DMA interface to external DMA controller.

The separate Data In (DBBIN) and Data Out (DBBOUT) registers greatly simplify the master/ UPI protocol compated to the UPI-41. The master need only check IBF before writing to DBBIN and OBF before reading DBBOUT. No data bus buffer lock-out is required.

The most significant nibble of the STATUS register, undefined in the UPI-41, is user-definable in UPI-41A. It may be loaded directly from the most significant nibble of the Accumulator (MOV STS,A). These extra four STATUS bits are useful for transferring additional status information to the master. This application note uses this feature extensively.

A new instruction, EN FLAGS, allows OBF and $\overline{\text{IBF}}$ to be reflected on PORT 2 BIT 4 and PORT 2 BIT 5 respectively. This feature enables interrupt-driven data transfers when these pins are interrupt sources to the master.

By executing an EN DMA instruction PORT 2 BIT 6 becomes a DRQ (DMA Request) output and PORT 2 BIT 7 becomes $\overline{\text{DACK}}$ (DMA Acknowledge). Setting DRQ requests a DMA cycle to an external DMA controller. When the cycle is granted, the DMA controller returns DACK plus either $\overline{\text{RD}}$ (Read) or $\overline{\text{WR}}$ (Write). DACK automatically forces

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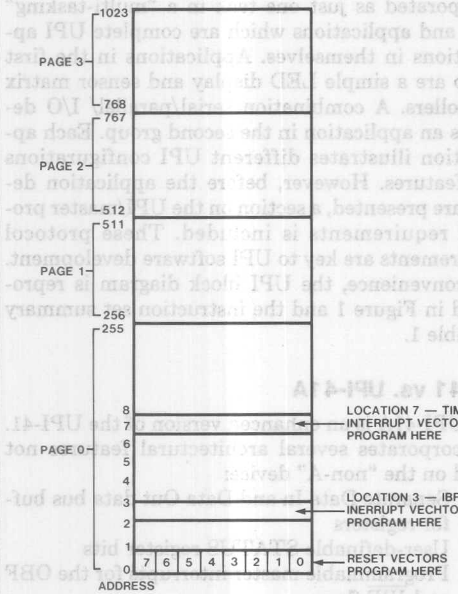

Figure 1A. Program Memory Map

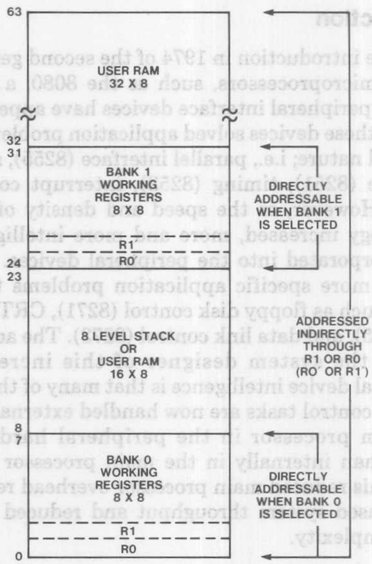

Figure 1B. Data Memory Map

$\overline{CS}$ and A_0 low internally and clears DRQ. This selects the appropriate data buffer register (DBBOUT for DACK and $\overline{RD}$, DBBIN for DACK and $\overline{WR}$) for the DMA transfer.

Like the "non-A", the UPI-41A is available in both ROM (8041A) and EPROM (8741A) Program Memory versions. This application note deals exclusively with the UPI-41A since the applications use the "A"s enhanced features.

UPI/MASTER PROTOCOL

As in most closely coupled multiprocessor systems, the various processors communicate via a shared resource. This shared resource is typically specific locations in RAM or in registers through which status and data are passed. In the case of a master processor and a UPI-41A, the shared resource is 3 separate, master-addressable, registers internal to the UPI. These registers are the status register (STATUS), the Data Bus Buffer Input register (DBBIN), and the Data Bus Output register (DBBOUT). [Data Bus Buffer direction is relative to the UPI]. To illustrate this register interface, consider the 8085A/UPI system in Figure 2.

Looking into the UPI from the 8085A, the 8085A sees only the three registers mentioned above. If the 8085A wishes to issue a command to the UPI, it does so by writing the command to the DBBIN register according to the decoding of Table 2. Data for the UPI is also passed via the DBBIN register. (The UPI differentiates commands and data by examining the A_0 pin. Just how this is done is covered shortly.) Data from the UPI for the 8085A is passed in the DBBOUT register. The 8085A may interrogate the UPI's status by reading the UPI's STATUS register. Four bits of the STATUS register act as flags and are used to handshake data and commands into and out of the UPI. The STATUS register format is shown in Figure 3.

BIT 0 is OBF (Output Buffer Full). This flag indicates to the master when the UPI has placed data in the DBBOUT register. OBF is set when the UPI writes to DBBOUT and is reset when the master reads DBBOUT. The master finds meaningful data in the DBBOUT register only when OBF is set.

The Input Buffer Full (IBF) flag is BIT 1. The UPI uses this flag as an indicator that the master has written to the DBBIN register. The master uses IBF

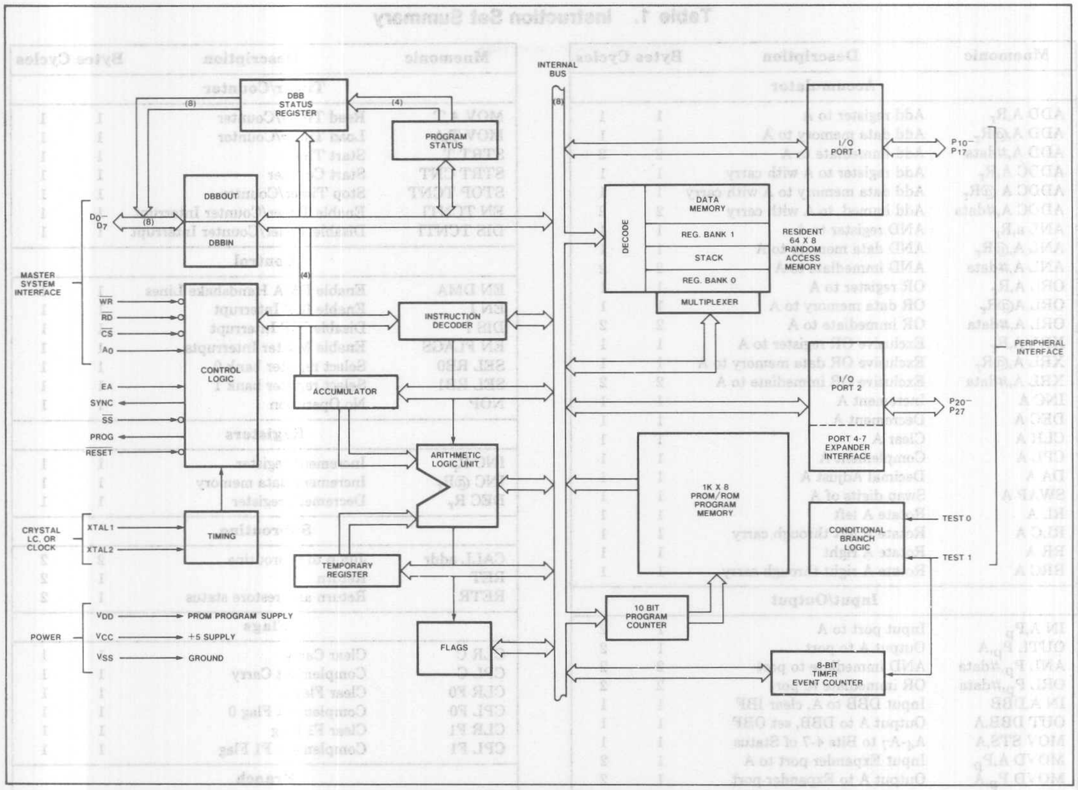

Figure 1C. UPI-41A Block Diagram

to indicate when the UPI has accepted a particular command or data byte. The master should examine IBF before outputting anything to the UPI. IBF is set when the master writes to DBBIN and is reset when the UPI reads DBBIN. The master must wait until IBF=0 before writing new data or commands to DBBIN. Conversely, the UPI must ensure IBF=1 before reading DBBIN.

The third STATUS register bit is F_0 (FLAG 0). This is a general purpose flag that the UPI can set, reset, and test. It is typically used to indicate a UPI error or busy condition to the master.

FLAG 1 (F_1) is the final dedicated STATUS bit. Like F_0 the UPI can set, reset, and test this flag. However, in addition, F_1 reflects the state of the A_0 pin whenever the master writes to the DBBIN register. The UPI uses this flag to delineate between master command and data writes to DBBIN.

The remaining four STATUS register bits are user definable. Typical uses of these bits are as status in-

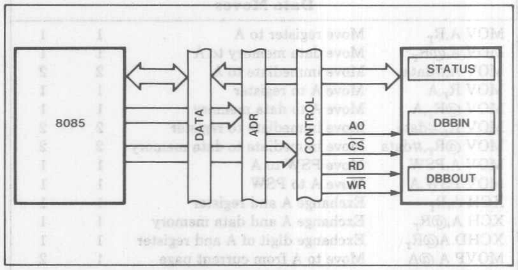

Figure 2. Register Interface

dicators for individual tasks in a multitasking UPI or as UPI generated interrupt status. These bits find a wide variety of uses in the upcoming applications.

Looking into the 8085A from the UPI, the UPI sees the two DBB registers plus the IBF, OBF, and F_1 flags. The UPI can write from its accumulator to DBBOUT or read DBBIN into the accumulator. The UPI cannot read OBF, IBF, or F_1 directly, but these flags may be tested using conditional jump

Table 1. Instruction Set Summary

Mnemonic	Description	Bytes	Cycles
Accumulator			
ADD A,R_r	Add register to A	1	1
ADD A,@R_r	Add data memory to A	1	1
ADD A,#data	Add immediate to A	2	2
ADDC A,R_r	Add register to A with carry	1	1
ADDC A @R_r	Add data memory to A with carry	1	1
ADDC A,#data	Add immed. to A with carry	2	2
ANL a,R_r	AND register to A	1	1
ANL A,@R_r	AND data memory to A	1	1
ANL A,#data	AND immediate to A	2	2
ORL A,R_r	OR register to A	1	1
ORL A@R_r	OR data memory to A	1	1
ORL A,#data	OR immediate to A	2	2
XRL A,R_r	Exclusive OR register to A	1	1
XRL A,@R_r	Exclusive OR data memory to A	1	1
XRL A,#data	Exclusive OR immediate to A	2	2
INC A	Increment A	1	1
DEC A	Decrement A	1	1
CLR A	Clear A	1	1
CPL A	Complement A	1	1
DA A	Decimal Adjust A	1	1
SWAP A	Swap digits of A	1	1
RL A	Rotate A left	1	1
RLC A	Rotate A left through carry	1	1
RR A	Rotate A right	1	1
RRC A	Rotate A right through carry	1	1
Input/Output			
IN A,P_p	Input port to A	1	2
OUTL P_p,A	Output A to port	1	2
ANL P_p,#data	AND immediate to port	2	2
ORL P_p,#data	OR immediate to port	2	2
IN A,DBB	Input DBB to A, clear IBF	1	1
OUT DBB,A	Output A to DBB, set OBF	1	1
MOV STS,A	A_4-A_7 to Bits 4-7 of Status	1	1
MOVD A,P_p	Input Expander port to A	1	2
MOVD P_p,A	Output A to Expander port	1	2
ANLD P_p,A	AND A to Expander port	1	2
ORLD P_p,A	OR A to Expander port	1	2
Data Moves			
MOV A,R_r	Move register to A	1	1
MOV A,@R_r	Move data memory to A	1	1
MOV A,#data	Move immediate to A	2	2
MOV R_r,A	Move A to register	1	1
MOV @R_r,A	Move A to data memory	1	1
MOV R_r,#data	Move immediate to register	2	2
MOV @R_r,#data	Move immediate to data memory	2	2
MOV A,PSW	Move PSW to A	1	1
MOV PSW,A	Move A to PSW	1	1
XCH A,R_r	Exchange A and register	1	1
XCH A,@R_r	Exchange A and data memory	1	1
XCHD A@R_r	Exchange digit of A and register	1	1
MOVP A,@A	Move to A from current page	1	2
MOVP3, A,@A	Move to A from page 3	1	2

Mnemonic	Description	Bytes	Cycles
Timer/Counter			
MOV A,T	Read Timer/Counter	1	1
MOV T,A	Load Timer/Counter	1	1
STRT T	Start Timer	1	1
STRT CNT	Start Counter	1	1
STOP TCNT	Stop Timer/Counter	1	1
EN TCNTI	Enable Timer/Counter Interrupt	1	1
DIS TCNTI	Disable Timer/Counter Interrupt	1	1
Control			
EN DMA	Enable DMA Handshake Lines	1	1
EN I	Enable IBF Interrupt	1	1
DIS I	Disable IBF Interrupt	1	1
EN FLAGS	Enable Master Interrupts	1	1
SEL RB0	Select register bank 0	1	1
SEL RB1	Select register bank 1	1	1
NOP	No Operation	1	1
Registers			
INC R_r	Increment register	1	1
INC @R_r	Increment data memory	1	1
DEC R_r	Decrement register	1	1
Subroutine			
CALL addr	Jump to subroutine	2	2
RET	Return	1	2
RETR	Return and restore status	1	2
Flags			
CLR C	Clear Carry	1	1
CPL C	Complement Carry	1	1
CLR F0	Clear Flag 0	1	1
CPL F0	Complement Flag 0	1	1
CLR F1	Clear F1 Flag	1	1
CPL F1	Complement F1 Flag	1	1
Branch			
JMP ADDR	Jump unconditional	2	2
JMPP @A	Jump indirect	1	2
DJNZ R,addr	Decrement register and skip	2	2
JC addr	Jump on Carry=1	2	2
JNC addr	Jump on Carry=0	2	2
JZ addr	Jump on A Zero	2	2
JNZ addr	Jump on A not Zero	2	2
JT0 addr	Jump on T0=1	2	2
JNT0 addr	Jump on T0=0	2	2
JT1 addr	Jump on T1=1	2	2
JNT1 addr	Jump on T1=0	2	2
JF0 addr	Jump on F0 Flag=1	2	2
JF1 addr	Jump on F1 Flag=1	2	2
JTF addr	Jump on Timer Flag=1,Clear Flag	2	2
JNIBF addr	Jump on IBF Flag=0	2	2
JOBF addr	Jump on OBF Flag=1	2	2
JBb addr	Jump on Accumulator Bit	2	2

Table 2. Register Decoding

CS	A0	RD	WR	REGISTER
0	0	0	1	READ DBBOUT
0	0	1	1	READ STATUS
0	0	1	0	WRITE DBBIN (DATA)
0	1	1	0	WRITE DBBIN (COMMAND)
1	X	X	X	NO ACTION

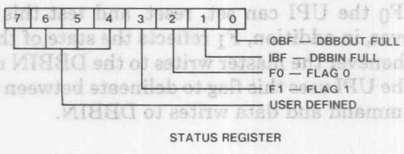

Figure 3. Status Register Format

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instructions. The UPI should make sure that OBF is reset before writing new data into DBBOUT to ensure that the master has read previous DBBOUT data. IBF should also be tested before reading DBBIN since DBBIN data is valid only when IBF is set. As was mentioned earlier, the UPI uses F_1 to differentiate between command and data contents in DBBIN when IBF is set. The UPI may also write the upper 4-bits of its accumulator to the upper 4-bits of the STATUS register. These bits are thus user definable.

The UPI can test the flags at any time during its internal program execution. It essentially "polls" the STATUS register for changes. If faster response is needed to master commands and data, the UPI's internal interrupt structure can be used. If IBF interrupts are enabled, a master write to DBBIN (either command or data) sets IBF which generates an internal CALL to location 03H in program memory. At this point, working register contents can be saved using bank switching, the accumulator saved in a spare working register, and the DBBIN register read and serviced. The interrupt logic for the IBF interrupt is shown in Figure 4. A few observations concerning this logic are appropriate. Note that if the master writes to DBBIN while the UPI is still servicing the last IBF interrupt (a RETR instruction has not been executed), the IBF Interrupt Pending line is made high which causes a new CALL to 03H as soon as the first RETR is executed. No EN I (Enable Interrupt) instruction is needed to rearm the interrupt logic as is needed in an 8080 or 8085A system; the RETR performs this function. Also note that executing a DIS I to disable further IBF interrupts does not clear a pending interrupt. Only a CALL to location 03H or RESET clears a pending IBF interrupt.

Keeping in mind that the actual master/UPI protocol is dependent on the application, probably the best way to illustrate correct protocol is by example. Let's consider using the UPI as a simple parallel I/O device. (This is a trivial application but it embodies all of the important protocol considerations.) Since the UPI may be either interrupt or non-interrupt driven internally, both cases are considered.

Let's take the easiest configuration first; using the UPI PORT 1 as an 8-bit output port. From the UPI's point-of-view, this is an input-only application since all that is required is that the UPI input data from the master. Once the master writes data to the UPI, the UPI reads the DBBIN register and transfers the data to PORT 1. No testing for commands versus data is needed since the UPI "knows" it only performs one task—no commands are needed.

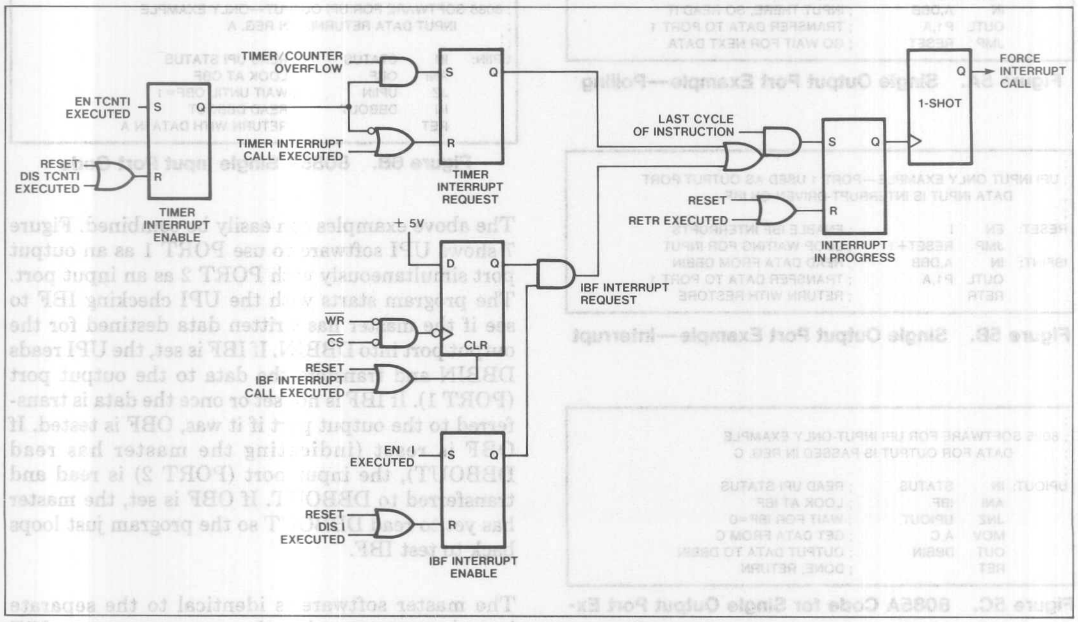

Figure 4. UPI-41A Interrupt Structure

Non-interrupt driven UPI software is shown in Figure 5A while Figure 5B shows interrupt based software. For Figure 5A, the UPI simply waits until it sees IBF go high indicating the master has written a data byte to DBBIN. The UPI then reads DBBIN, transfers it to PORT 1, and returns to waiting for the next data. For the interrupt-driven UPI, Figure 5B, once the EN I instruction is executed, the UPI simply waits for the IBF interrupt before handling the data. The UPI could handle other tasks during this waiting time. When the master writes the data to DBBIN, an IBF interrupt is generated which performs a CALL to location 03H. At this point the UPI reads DBBIN (no testing of IBF is needed since an IBF interrupt implies that IBF is set), transfers the data to PORT 1, and executes an RETR which returns program flow to the main program.

Software for the master 8085A is included in Figure 5C. The only requirement for the master to output data to the UPI is that it check the UPI to be sure the previous data had been taken before writing new data. To accomplish this the master simply reads the STATUS register looking for IBF=0 before writing the next data.

```
;
; UPI INPUT ONLY EXAMPLE—PORT 1 USED AS OUTPUT PORT
;        UPI POLLS IBF FOR DATA
;
RESET:  JNIBF  RESET      ; WAIT ON IBF FOR INPUT
        IN     A,DBB      ; INPUT THERE, SO READ IT
        OUTL   P1,A       ; TRANSFER DATA TO PORT 1
        JMP    RESET      ; GO WAIT FOR NEXT DATA
```

Figure 5A. Single Output Port Example—Polling

```
;
; UPI INPUT ONLY EXAMPLE—PORT 1 USED AS OUTPUT PORT
;        DATA INPUT IS INTERRUPT-DRIVEN ON IBF
;
RESET:  EN     I          ; ENABLE IBF INTERRUPTS
        JMP    RESET+1    ; LOOP WAITING FOR INPUT
IBFINT: IN     A,DBB      ; READ DATA FROM DBBIN
        OUTL   P1,A       ; TRANSFER DATA TO PORT 1
        RETR              ; RETURN WITH RESTORE
```

Figure 5B. Single Output Port Example—Interrupt

```
;
; 8085 SOFTWARE FOR UPI INPUT-ONLY EXAMPLE
;        DATA FOR OUTPUT IS PASSED IN REG. C
;
UPIOUT: IN     STATUS     ; READ UPI STATUS
        ANI    IBF        ; LOOK AT IBF
        JNZ    UPIOUT     ; WAIT FOR IBF=0
        MOV    A,C        ; GET DATA FROM C
        OUT    DBBIN      ; OUTPUT DATA TO DBBIN
        RET               ; DONE, RETURN
```

Figure 5C. 8085A Code for Single Output Port Example

Figure 6A illustrates the case where UPI PORT 2 is used as an 8-bit input port. This configuration is termed UPI output-only as the master does not write (input) to the UPI but simply reads either the STATUS or the DBBOUT registers. In this example only the OBF flag is used. OBF signals the master that the UPI has placed new port data in DBBOUT. The UPI loops testing OBF. When OBF is clear, the master has read the previous data and UPI then reads its input port (PORT 2) and places this data in DBBOUT. It then waits on OBF until the master reads DBBOUT before reading the input port again. When the master wishes to read the input port data, Figure 6B, it simply checks for OBF being set in the STATUS register before reading DBBOUT. While this technique illustrates proper protocol, it should be noted that it is not meant to be a good method of using the UPI as an input port since the master would never get the newest status of the port.

```
; UPI OUTPUT ONLY EXAMPLE—PORT 2 USED AS INPUT PORT
;        PORT DATA IS AVAILABLE IN DBBOUT
;
RESET:  JOBF   RESET      ; LOOP IF OBF=1 (DATA NOT READ)
        IN     A,P2       ; DBBOUT CLEAR, READ PORT
        OUT    DBB,A      ; TRANSFER PORT DATA TO DBBOUT
        JMP    RESET      ; WAIT FOR MASTER TO READ DATA
```

Figure 6A. Single Input Port Example

```
;
; 8085 SOFTWARE FOR UPI OUTPUT—ONLY EXAMPLE
;        INPUT DATA RETURNED IN REG. A
;
UPIIN:  IN     STATUS     ; READ UPI STATUS
        ANI    OBF        ; LOOK AT OBF
        JZ     UPIIN      ; WAIT UNTIL OBF=1
        IN     DBBOUT     ; READ DBBOUT
        RET               ; RETURN WITH DATA IN A
```

Figure 6B. 8085A Single Input Port Code

The above examples can easily be combined. Figure 7 shows UPI software to use PORT 1 as an output port simultaneously with PORT 2 as an input port. The program starts with the UPI checking IBF to see if the master has written data destined for the output port into DBBIN. If IBF is set, the UPI reads DBBIN and transfers the data to the output port (PORT 1). If IBF is not set or once the data is transferred to the output port if it was, OBF is tested. If OBF is reset (indicating the master has read DBBOUT), the input port (PORT 2) is read and transferred to DBBOUT. If OBF is set, the master has yet to read DBBOUT so the program just loops back to test IBF.

The master software is identical to the separate input/output examples; the master must test IBF

```
;
; UPI INPUT/OUTPUT EXAMPLE—PORT 1OUTPUT, PORT 2 INPUT
;
RESET:  JNIBF   OUT1       ; IF IBF=0, DO OUTPUT
        IN      A, DBB     ; IF IBF=1, READ DBBIN
        OUTL    P1, A      ; TRANSFER DATA TO PORT 1
OUT1:   JOBF    RESET      ; IF OBF=1, GO TEST IBF
        IN      A, P2      ; IF OBF=0, READ PORT 2
        OUT     DBB, A     ; TRANSFER PORT DATA TO DBBOUT
        JMP     RESET      ; GO CHECK FOR INPUT
```

Figure 7. Combination Output/Input Port Example

and OBF before writing output port data into DBBIN or before reading input port from DBBOUT respectively.

In all of the three examples above, the UPI treats information from the master solely as data. There has been no need to check if DBBIN information is a command rather than data since the applications do not require commands. But what if both PORTs 1 and 2 were used as output ports? The UPI needs to know into which port to put the data. Let's use a command to select which port.

Recall that both commands and data pass through DBBIN. The state of the A_0 pin at the time of the write to DBBIN is used to distinguish commands from data. By convention, DBBIN writes with A_0=0 are for data, and those with A_0=1 are commands. When DBBIN is written into, F_1 (FLAG 1) is set to the state of A_0. The UPI tests F_1 to determine if the information in the DBBIN register is data or command.

For the case of two output ports, let's assume that the master selects the desired port with a command prior to writing the data. (We could just use F_1 as a port select but that would not illustrate the subtle differences between commands and data). Let's define the port select commands such that BIT 1=1 if the next data is for PORT 1 (Write PORT 1=0000 0010) and BIT 2=1 if the next data is for PORT 2 (Write PORT 2=0000 0100). (The number of the set bit selects the port.) Any other bits are ignored. This assignment is completely arbitrary; we could use any command structure, but this one has the advantage of being simple.

Note that the UPI must "remember" from DBBIN write to write which port has been selected. Let's use F_0 (FLAG 0) for this purpose. If a Write PORT 1 command is received, F_0 is reset. If the command is Write PORT 2, F_0 is set. When the UPI finds data in DBBIN, F_0 is interrogated and the data is loaded into the previously selected port. The UPI software is shown in Figure 8A.

```
;
; UPI DUAL OUTPUT PORT EXAMPLE—BOTH PORT 1 AND 2 OUTPUTS
;         COMMAND SELECTS DESIRED PORT
;         WRITE PORT 1—0000 0010 (02H)
;         WRITE PORT 2—0000 0100 (04H)
;
;         FLAG 0 USED TO REMEMBER WHICH PORT WAS SELECTED
;         BY LAST COMMAND.
;
RESET:  JNIBF   RESET      ; WAIT FOR MASTER INPUT
        IN      A, DBB     ; READ INPUT
        JF1     CMD        ; IF F1=1, COMMAND INPUT
        JF0     PORT2      ; INPUT IS DATA, TEST F0
        OUTL    P1,A       ; F0=0, SO OUTPUT TO PORT 1
        JMP     RESET      ; WAIT FOR NEXT INPUT
PORT2:  OUTL    P2,A       ; F0=1, SO OUTPUT TO PORT 2
        JMP     RESET      ; WAIT FOR NEXT INPUT
CMD:    JB1     PT1        ; TEST COMMAND BITS (BIT 1)
        JB2     PT2        ; TEST BIT 2
        JMP     RESET      ; NEITHER BIT SET, WAIT FOR INPUT
PT1:    CLR     F0         ; PORT 1 SELECTED, CLEAR F0
        JMP     RESET      ; WAIT FOR INPUT
PT2:    CLR     F0         ; PORT 2 SELECTED, SET F0
        CPL     F0
        JMP     RESET      ; WAIT FOR INPUT
```

Figure 8A. Dual Output Port Example

Initially, the UPI simply waits until IBF is set indicating the master has written into DBBIN. Once IBF is set, DBBIN is read and F_1 is tested for a command. If F_1=1, the DBBIN byte is a command. Assuming a command, BIT 1 is tested to see if the command selected PORT 1. If so, F_0 is cleared and the program returns to wait for the data. If BIT 1=0, BIT 2 is tested. If BIT 2 is set, PORT 2 is selected so F_0 is set. The program then loops back waiting for the next master input. This input is the desired port data. If BIT 2 was not set, F_0 is not changed and no action is taken.

When IBF=1 is again detected, the input is again tested for command or data. Since it is necessarily data, DBBIN is read and F_0 is tested to determine which port was previously selected. The data is then output to that port, following which the program waits for the next input. Note that since F_0 still selects the previous port, the next input could be more data for that port. The port selection command could be thought of as a port select flip-flop control; once a selection is made, data may be repeatedly written to that port until the other port is selected. Master software, Figure 8B, simply must check IBF before writing either a command or data to DBBIN. Otherwise, the master software is straightforward.

For the sake of completeness, UPI software for implementing two input ports is given in Figure 9. This case is simpler than the dual output case since the UPI can assume that all writes to DBBIN are port selection commands so no command/data testing is required. Once the Port Read command is input, the selected port is read and the port data is placed in DBBOUT. Note that in this case F_0 is used as a UPI

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error indicator. If the master happened to issue an invalid command (a command without either BIT 1 or 2 set), F_0 is set to notify the master that the UPI did not know how to interpret the command. F_0 is also set if the master commanded a port read before it had read DBBOUT from the previous command. The UPI simply tests OBF just prior to loading DBBOUT and if OBF=1, F_0 is set to indicate the error.

All of the above examples are, in themselves, rather trivial applications of the UPI although they could easily be incorporated as one of several tasks in a UPI handling multiple small tasks. We have covered them primarily to introduce the UPI concept and to illustrate some master/UPI protocol. Before moving on to more realistic UPI applications, let's discuss two UPI features that do not directly relate to the master/UPI protocol but greatly enhance the UPI's transfer capability.

In addition to the OBF and IBF bits in the STATUS register, these flags can also be made available directly on two port pins. These port pins can then be used as interrupt sources to the master. By executing an EN FLAGS instruction, PORT 2 pin 4 reflects the condition of OBF and PORT 2 pin 5 reflects the inverted condition of IBF ($\overline{IBF}$). These dedicated outputs can then be enabled or disabled via their respective port bit values; i.e., P_{24} reflects OBF as long as an instruction is executed which sets P_{24} (i.e. ORL P2,#10H). The same action applies to the $\overline{IBF}$ output except P_{25} is used. Thus P_{24} may serve as a DATA AVAILABLE interrupt output. Likewise for P_{25} as a READY-TO-ACCEPT-DATA interrupt. This greatly simplifies interrupt-driven master-slave data transfers.

```
;
; 8085 SOFTWARE FOR DUAL OUTPUT PORT EXAMPLE
;       THIS ROUTINE WRITES DATA IN REG. C TO PORT 1
;       (SAME ROUTINE FOR PORT 2—JUST CHANGE COMMAND)
;
PORT1:  IN    STATUS      ; READ UPI STATUS
        ANI   IBF         ; LOOK AT IBF
        JNZ   PORT1       ; WAIT UNTIL IBF=0
        MVI   A, 00000010B ; LOAD WRITE PORT1 CMD
        OUT   UPICMD      ; OUTPUT TO UPI COMMAND PORT
P1:     IN    STATUS      ; READ UPI STATUS AGAIN
        ANI   IBF         ; LOOK AT IBF
        JNZ   P1          ; WAIT UNTIL COMMAND ACCEPTED
        MOV   A, C        ; GET DATA FROM C
        OUT   DBBIN       ; OUTPUT TO DBBIN
        RET               ; DONE, RETURN
```

Figure 8B. 8085A Dual Output Port Example Code

The UPI also supports a DMA transfer interface. If an EN DMA instruction is executed, PORT 2 pin 6 becomes a DMA Request (DRQ) output and P_{27} becomes a high impedance DMA Acknowledge

```
;
; UPI DUAL INPUT PORT EXAMPLE—BOTH PORT 1 AND 2 INPUTS
;       COMMAND SELECTS WHICH PORT IS TO BE READ
;       FLAG 0 USED AS ERROR FLAG
;
RESET:  JNIBF  RESET   ; WAIT FOR INPUT
        CLR    F0      ; CLEAR ERROR FLAG
        IN     A, DBB  ; READ INPUT (COMMAND)
        JB1    PT1     ; TEST BIT 1 (PORT 1)
        JB2    PT2     ; TEST BIT 2 (PORT 2)
ERROR:  CPL    F0      ; ERROR—COMPLEMENT F0
        JMP    RESET   ; WAIT FOR INPUT
PT1:    IN     A, P1   ; READ PORT 1
        JOBF   ERROR   ; TEST OBF BEFORE LOADING DBBOUT
        OUT    DBB, A  ; LOAD PORT 1 DATA INTO DBBOUT
        JMP    RESET   ; WAIT FOR INPUT
PT2:    IN     A, P2   ; READ PORT 2
        JOBF   ERROR   ; TEST OBF BEFORE LOADING DBBOUT
        OUT    DBB, A  ; LOAD PORT 2 DATA INTO DBBOUT
        JMP    RESET   ; WAIT FOR INPUT
```

Figure 9. Dual Input Port Example

($\overline{DACK}$) input. Any instruction which would normally set P_{26} now sets DRQ. DRQ is cleared when $\overline{DACK}$ is low and either $\overline{RD}$ or $\overline{WR}$ is low. When $\overline{DACK}$ is low, $\overline{CS}$ and A0 are forced low internally which allows data bus transfers between DBBOUT or DBBIN to occur, depending upon whether $\overline{WR}$ or $\overline{RD}$ is true. Of course, the function requires the use of an external DMA controller.

Now that we have discussed the aspects of the UPI protocol and data transfer interfaces, let's move on to the actual applications.

EXAMPLE APPLICATIONS

Each of the following three sections presents the hardware and software details of a UPI application. Each application utilizes one of the protocols mentioned in the last section. The first example is a simple 8-digit LED display controller. This application requires only that the UPI perform input operations from the DBBIN; DBBOUT is not used. The reverse is true for the second application: a sensor matrix controller. The final application involves both DBBOUT and DBBIN operations: a combination serial/parallel I/O device.

The core master processor system with which these applications were developed is the iSBC 80/30 single board computer. This board provides an especially convenient UPI environment since it contains a dedicated socket specifically interfaced for the UPI-41A. The 80/30 uses the 8085A as the master processor. The I/O and peripheral complement on the 80/30 include 12 vectored priority interrupts (8 on an 8259 Programmable Interrupt Controller and 4 on the 8085A itself), an 8253 Programmable Interval Timer supplying three 16-bit programmable timers (one is dedicated as a programmable baud rate generator), a high speed serial channel provided by a 8251 Programmable USART, and 24 parallel I/O

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lines implemented with an 8255A Programmable Parallel Interface. The memory complement contains 16K bytes of RAM using 2117 16K bit Dynamic RAMs and the 8202 Dynamic RAM Controller, and up to 8K bytes of ROM/EPROM with sockets compatible with 2716, 2758, or 2332 devices. The 80/30's RAM uses a dual port architecture. That is, the memory can be considered a global system resource, accessible from the on-board 8085A as well as from remote CPUs and other devices via the MULTIBUS. The 80/30 contains MULTIBUS control logic which allows up to 16 80/30s or other bus masters to share the same system bus. (More detailed information on the iSBC 80/30 and other iSBC products may be found in the latest Intel *Systems Data Catalog.*)

A block diagram of the iSBC 80/30 is shown in Figure 10. Details of the UPI interface are shown in Figure 11. This interface decodes the UPI registers in the following format:

Register	Operations
Read STATUS	IN E5H
Write DBBIN (command)	OUT E5H
Read DBBOUT (data)	IN E4H
Write DBBIN (data)	OUT E4H

8-Digit Multiplexed LED Display

The traditional method of interfacing an LED display with a microprocessor is to use a data latch along with a BDC-to-7-segment decoder for each digit of the display. Thus two ICs, seven current limiting resistors, and about 45 connections are required for each digit. These requirements are, of course, multiplied by the total number of digits desired. The obvious disadvantages of this method are high parts count and high power dissipation since each digit is "ON" continuously. Instead, a scheme of time multiplexing the display can be used to decrease both parts count and power dissipation.

Display multiplexing basically involves connecting the same segment (a, b, c, d, e, f, or g) of each digit in parallel and driving the common digit element (anode or cathode) of each digit separately. This is shown schematically in Figure 12. The various digits of the display are not all on at once; rather, only one digit at a time is energized. As each digit is energized, the appropriate segments for that digit are turned on. Each digit is enabled in this way, in sequence, at a rate fast enough to ensure that each digit appears to be "ON" continuously. This implies that the display must be "refreshed" at periodic intervals to keep the digits flicker-free. If the CPU had to handle this task, it would have to suspend normal processing, go update the display, and then return to its normal flow. This extra burden is ideally handled by a UPI. The master CPU could simply give characters to the UPI and let the UPI do the actual segment decoding, display multiplexing, and refreshing.

As an example of this technique, Figure 13 shows the UPI controlling an 8-digit LED display. All digit segments are connected in parallel and are driven through segment drivers by the UPI PORT 1. The lower 3 bits of PORT 2 are inputs to a 3-to-8 decoder which selects an individual digit through a digit driver. A fourth PORT 2 line is used as a decoder enable input. The remaining PORT 2 lines plus the TEST 0 and TEST 1 inputs are available for other tasks.

Internally, the UPI uses the counter/timer in the interval timer mode to define the interval between display refreshes. Once the timer is loaded with the desired interval and started, the UPI is free to handle other tasks. It is only when a timer overflow interrupt occurs that the UPI handles the short display multiplexing routine. The display multiplexing can be considered a background task which is entirely interrupt-driven. The amount of time spent multiplexing is such that there is ample time to handle a non-timer task in the UPI foreground. (We'll discuss this timing shortly.)

When a timer interrupt occurs, the UPI turns off all digits via the decoder enable. The next digit's segment contents are retrieved from the internal data memory and output via PORT 1 to the segment drivers. Finally, the next digit's location is placed on PORT 2 (P_{20}–P_{22}) and the decoder enabled. This displays the digit's segment information until the next interrupt. The timer is then restarted for the next interval. This process continues repeatedly for each digit in sequence.

As a prelude to discussing the UPI software, let's examine the internal data memory structure used in this application, Figure 14. This application requires only 14 of the 64 total data memory locations. The top eight locations are dedicated to the Display Map; one location for each digit. These locations contain the segment and decimal point information for each character. Just how characters are loaded into this section of memory is covered shortly. Register R_7 of Register Bank 1 is used as the temporary Accumulator store during the interrupt service routines. Register R_3 stores the digit number of the next digit to be displayed. R_2 is a temporary storage register for characters during input routine. R_0 is

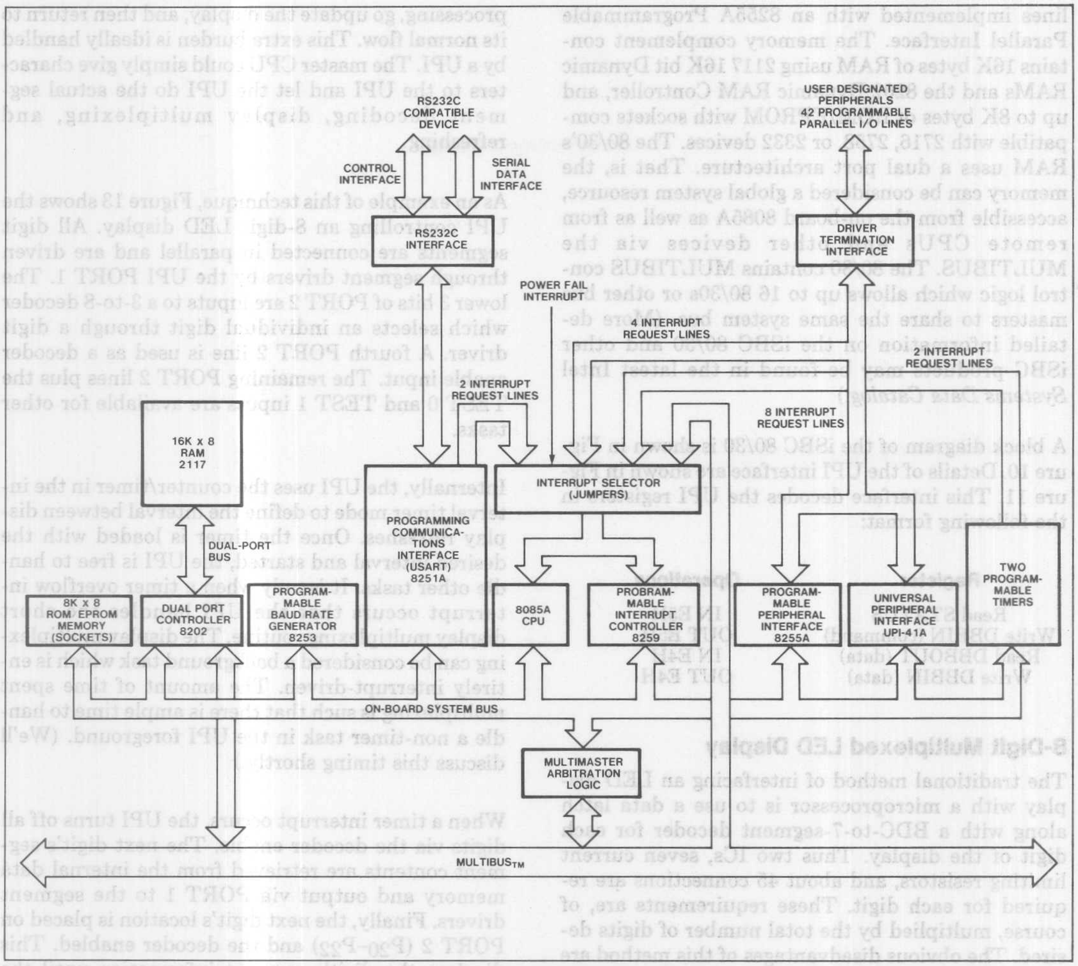

Figure 10. iSBC 80/30 Block Diagram

the offset pointer pointing to the Display Map location of the next digit. That makes 12 locations so far. The remaining two locations are the two stack locations required to store the return address plus status during the timer and input interrupt service routines. The remaining unused locations, all of Register Bank 0, 14 bytes of stack, 4 in Register Bank 1, and 24 general purpose RAM locations, are all available for use by any foreground task.

The UPI software consists of only three short routines. One, INIT, is used strictly during initialization. DISPLA is the multiplexing routine called at a timer interrupt. INPUT is the character input handler called at an IBF interrupt. The flow charts for these routines are shown in Figures 14A through 14C.

INIT initializes the UPI by simply turning off all segment and digit drivers, filling the Display Map with blank characters, loading and starting the timer, and enabling both timer and IBF interrupts. Although the flow chart shows the program looping at this point, it is here that the code for any foreground task is inserted. The only restrictions on this foreground task are that it not use I/O lines dedicated to the display and that it not require dedicated use of the timer. It could share the timer if precautions are taken to ensure that the display will still be refreshed at the required interval.

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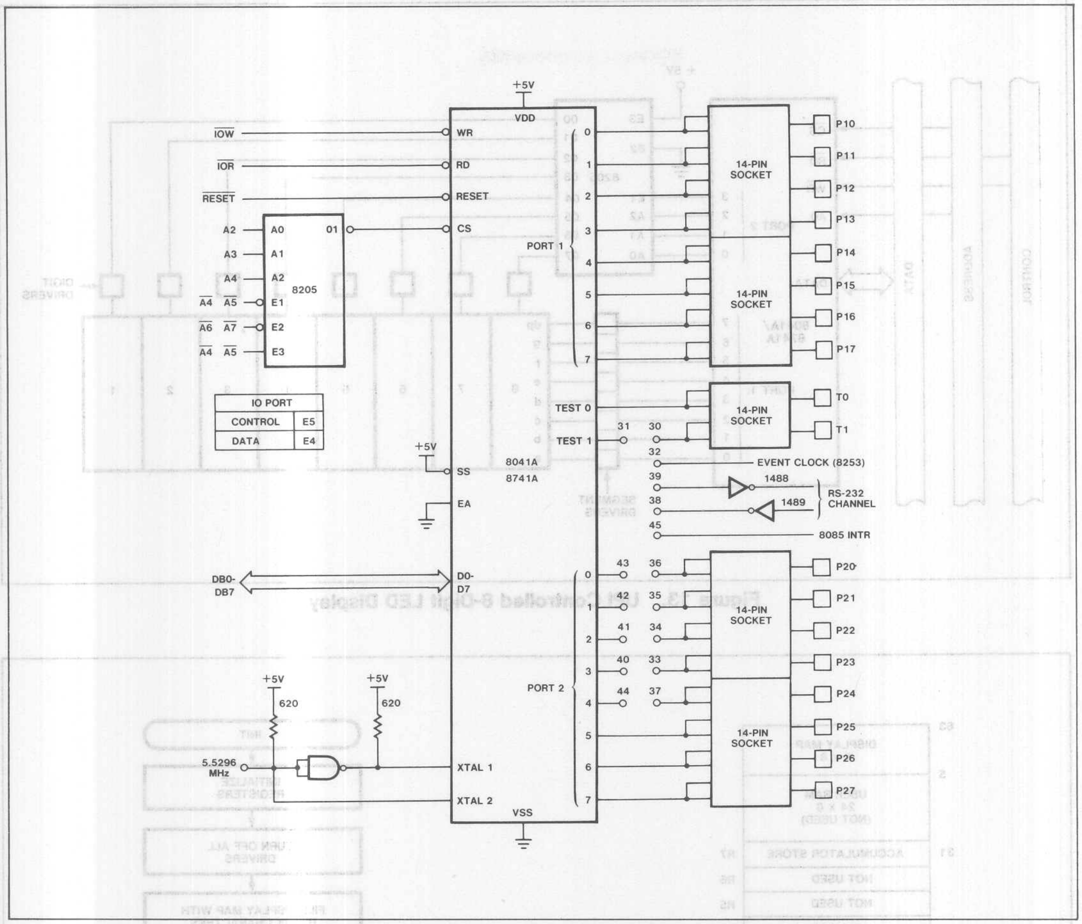

Figure 11. UPI Interface on iSBC 80/30

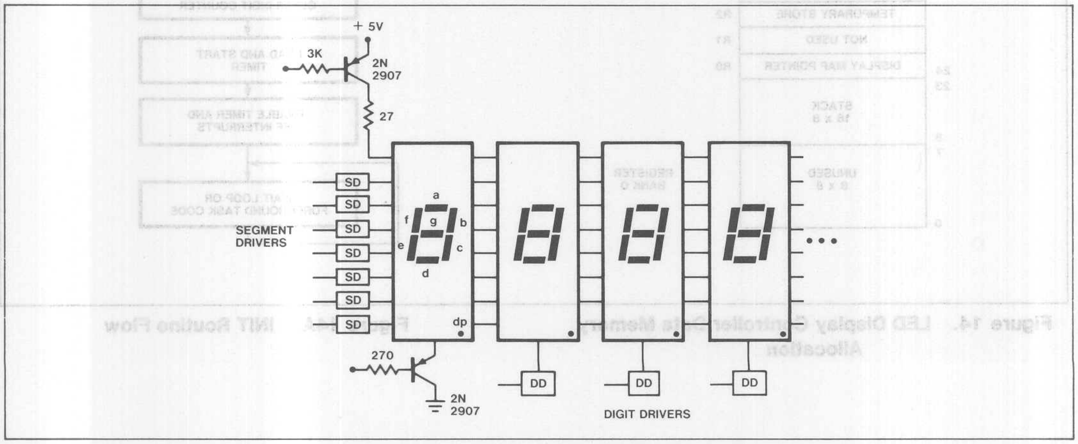

Figure 12. LED Multiplexing

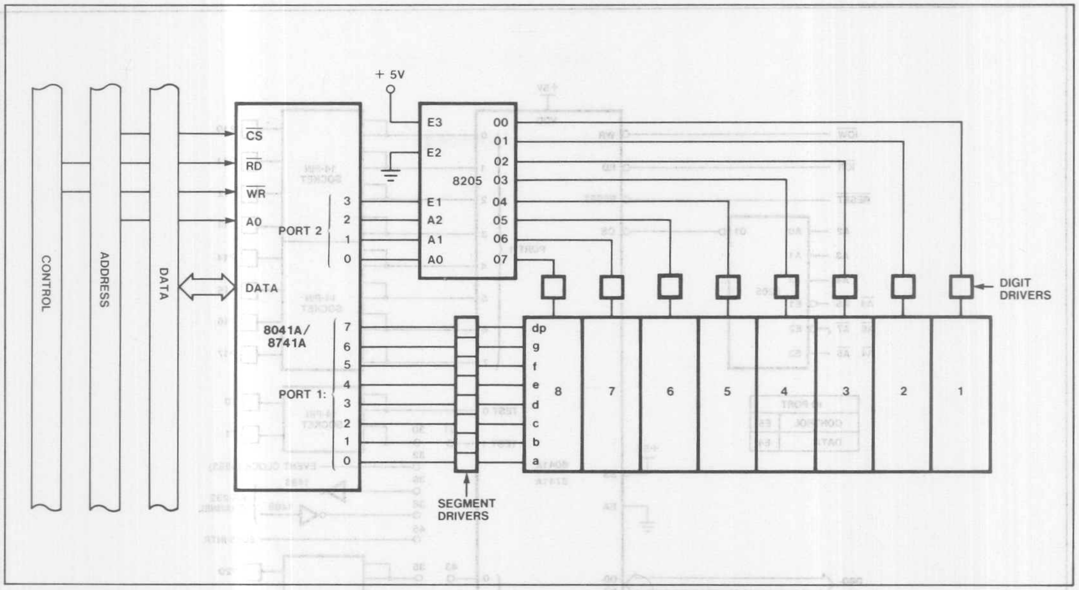

Figure 13. UPI Controlled 8-Digit LED Display

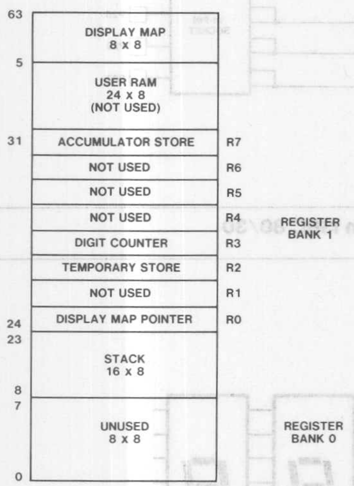

Figure 14. LED Display Controller Data Memory Allocation

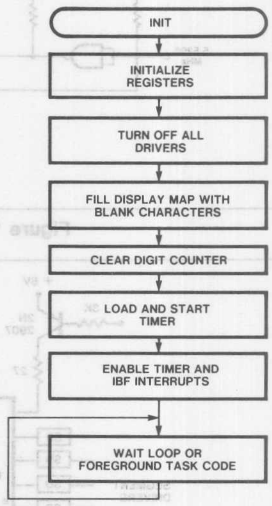

Figure 14A. INIT Routine Flow

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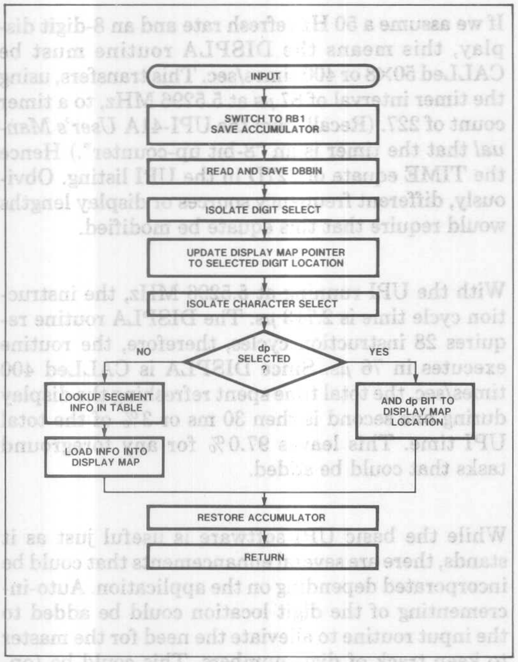

Figure 14B. INPUT Routine Flow

The INPUT routine handles the character input. It is called when an IBF interrupt occurs. After the usual swapping of register banks and saving of the accumulator, DBBIN is read and stored in register R_2. DBBIN contains the Display Data Word. The format for this word, Figure 15, has two fields: Digit Select and Character Select. The Digit Select field selects the digit number into which the character from the Character Select field is placed. Notice that the character set is not limited strictly to numerics, some alphanumeric capability is provided. Once DBBIN is read, the offset for the selected digit is computed and placed in the Display Map Pointer R_0. Next the segment information for the selected character is found through a look-up table starting in page 3 of the program memory. This segment information is then stored at the location pointed at by the Display Map Pointer. If the Character Select field specified a decimal point, the segment corresponding to the decimal point is ANDed into the present segment information for that digit. After the accumulator is restored, execution is returned to the main program.

The DISPLA routine simply implements the multiplexing actions described earlier. It is called whenever a timer interrupt occurs. After saving pre-

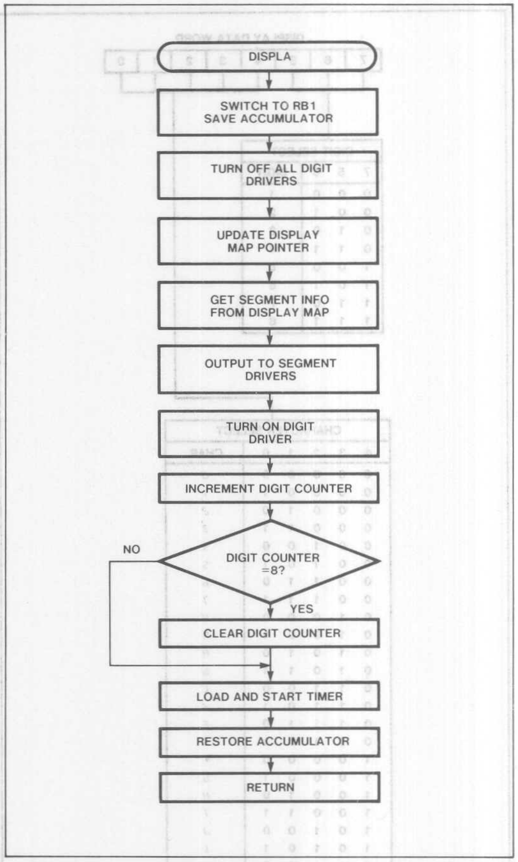

Figure 14C. DISPLA Routine Flow

interrupt status by switching register banks and storing the Accumulator, all digit drivers are turned off. The Display Map Pointer is then updated using the Current Digit Register to point at that digit's segment information in the Display Map. This information is output to PORT 1; the segment drivers. The number of the current digit, R_3, is then sent to the digit select decoder and the decoder is enabled. This turns on the current digit. The digit counter is incremented and tested to see if all eight digits have been refreshed. If so, the digit counter is reset to zero. If not, nothing is done. Finally, the timer is loaded and restarted, the Accumulator is restored, and the routine returns execution to the main program. Thus DISPLA refreshes one digit each time it is CALLed by the timer interrupt. The digit remains on until the next time DISPLA is executed.

The UPI software listing is included as Appendix A1. Appendix A2 shows the 8085A test routine used

DISPLAY DATA WORD

7	6	5	4	3	2	1	0

DIGIT SELECT

7	5	6	DIGIT
0	0	0	1
0	0	1	2
0	1	0	3
0	1	1	4
1	0	0	5
1	0	1	6
1	1	0	7
1	1	1	8

CHARACTER SELECT

4	3	2	1	0	CHAR
0	0	0	0	0	0
0	0	0	0	1	1
0	0	0	1	0	2
0	0	0	1	1	3
0	0	1	0	0	4
0	0	1	0	1	5
0	0	1	1	0	6
0	0	1	1	1	7
0	1	0	0	0	8
0	1	0	0	1	9
0	1	0	1	0	A
0	1	0	1	1	b
0	1	1	0	0	C
0	1	1	0	1	d
0	1	1	1	0	E
0	1	1	1	1	F
1	0	0	0	0	•
1	0	0	0	1	G
1	0	0	1	0	H
1	0	0	1	1	I
1	0	1	0	0	J
1	0	1	0	1	L
1	0	1	1	0	n
1	0	1	1	1	o
1	1	0	0	0	P
1	1	0	0	1	r
1	1	0	1	0	t
1	1	0	1	1	U
1	1	1	0	0	Y
1	1	1	0	1	-
1	1	1	1	0	.
1	1	1	1	1	blank

Figure 15. LED Display Controller Display Data Word Format

to display the contents of a display buffer on the display. The 8085A software takes care of the display digit numbering. Since the application is input-only for the UPI, the only protocol required is that the master must test IBF before writing a Display Data Word into DBBIN.

On the iSBC 80/30, the UPI frequency is at 5.5296 MHz. To obtain a flicker-free display, the whole display must be refreshed at a rate of 50 Hz or greater.

If we assume a 50 Hz refresh rate and an 8-digit display, this means the DISPLA routine must be CALLed 50×8 or 400 times/sec. This transfers, using the timer interval of 87 μs at 5.5296 MHz, to a timer count of 227. (Recall from the UPI-41A *User's Manual* that the timer is an "8-bit up-counter".) Hence the TIME equate of 227D in the UPI listing. Obviously, different frequency sources or display lengths would require that this equate be modified.

With the UPI running at 5.5296 MHz, the instruction cycle time is 2.713 μs. The DISPLA routine requires 28 instruction cycles, therefore, the routine executes in 76 μs. Since DISPLA is CALLed 400 times/sec, the total time spent refreshing the display during one second is then 30 ms or 3% of the total UPI time. This leaves 97.0% for any foreground tasks that could be added.

While the basic UPI software is useful just as it stands, there are several enhancements that could be incorporated depending on the application. Auto-incrementing of the digit location could be added to the input routine to alleviate the need for the master to keep track of digit numbers. This could be (optionally) either right-handed or left-handed entry a la TI or HP calculators. The character set could be easily modified by simply changing the lookup table. The display could be expanded to 16 digits at the expense of one additional PORT 2 digit select line, the replacement of the 3-to-8 decoder with a 4-to-16 decoder, and 8 more Display Map locations.

Now let's move on to a slightly more complex application that is UPI output-only—a sensor matrix controller.

Sensor Matrix Controller

Quite often a microprocessor system is called upon to read the status of a large number of simple SPST switches or sensors. This is especially true in a process or industrial control environment. Alarm systems are also good examples of systems with a large sensor population. If the number of sensors is small, it might be reasonable to dedicate a single input port pin for each sensor. However, as the number of sensors increase, this technique becomes very wasteful. A better arrangement is to configure the sensors in a matrix organization like that shown in Figure 16. This arrangement of 16 sensors requires only 4 input and 4 output lines; half the number needed if dedicated inputs were used. The line saving becomes even more substantial as the number of sensors increases.

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In Figure 16, the basic operation of the matrix involves scanning individual row select lines in sequence while reading the column return lines. The state of any particular sensor can then be determined by decoding the row and column information. The typical configuration pulls up the column return lines and the selected row is held low. Deselected rows are held high. Thus a return line remains high for an open sensor on the selected row and is pulled low for a closed sensor. Diode isolation is used to prevent a phantom closure which would occur when a sensor is closed on a selected row and there are two or more closures on a deselected row. Germanium diodes are used to provide greater noise margin at the return line input.

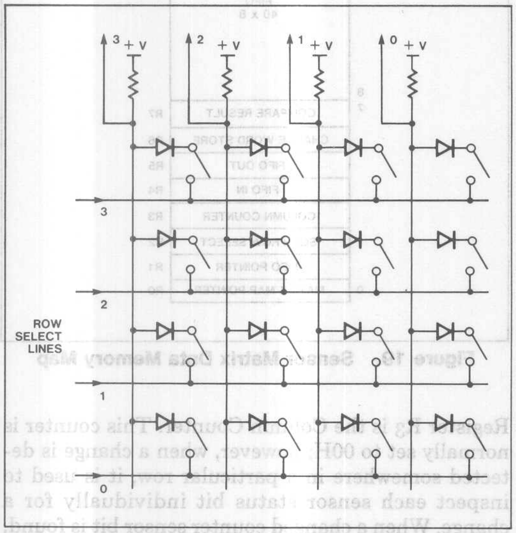

Figure 16. 4×4 Sensor Matrix

If the main processor was required to control such a matrix it would periodically have to output at the row port and then read the column return port. The processor would need to maintain in memory a map of the previous state of the matrix. A comparison of the new return information to the old information would then be made to determine whether a sensor change had occurred. Any changes would be processed as needed. A row counter and matrix map pointer also require maintenance each scan. Since in most applications sensors change very slowly compared to most processing actions, the processor probably would scan the rows only periodically with other tasks being processed between scans.

Rather than require the processor to handle the rather mundane tasks of scanning, comparing, and decoding the matrix, why not use a dedicated processor? The UPI is perfect.

Figure 17 shows a UPI configuration for controlling up to 128 sensors arranged in a 16×8 matrix. The 4-to-16 line decoder is used as the row selector to save port pins and provides the expansion to 128 sensors over the maximum of 64 sensors if the port had been used directly. It also helps increase the port drive capability. The column return lines go directly into PORT 1. Features of this design include complete matrix management. As the UPI scans the matrix it compares its present status to the previous scan. If any change is detected, the location of the change is decoded and loaded, along with the sensor's present state, into DBBOUT. This byte is called a Change Word. The Master processor has only to read one byte to determine the status and coordinate of a changed sensor. If the master had not read a previous Change Word in DBBOUT (OBF=1) before a new sensor change is detected, the new Change

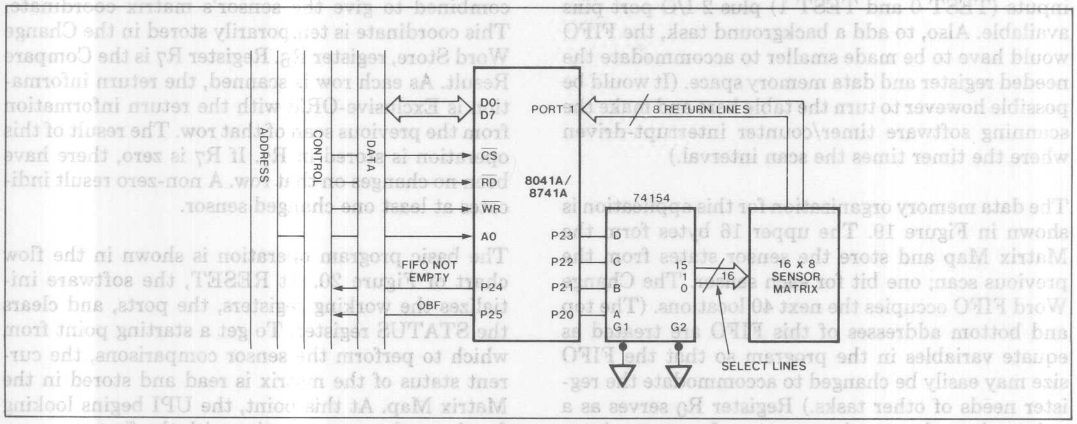

Figure 17. 128 Sensor Matrix Controller

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Word is loaded into an internal FIFO. This FIFO buffers up to 40 changes before it fills. The status of the FIFO and OBF is made available to the master either by polling the UPI STATUS register, Figure 18A, or as interrupt sources on port pins P_{24} and P_{25} respectively, Figure 17. The FIFO NOT EMPTY pin and bit are true as long as there are changes not yet read in the FIFO. As long as the FIFO is not empty, the UPI monitors OBF and loads new Change Words from the FIFO into DBBOUT. Thus, the UPI provides complete FIFO management.

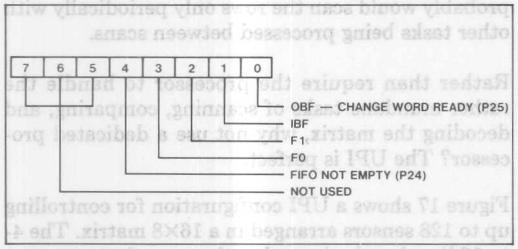

Figure 18A. Sensor Matrix Status Register Format

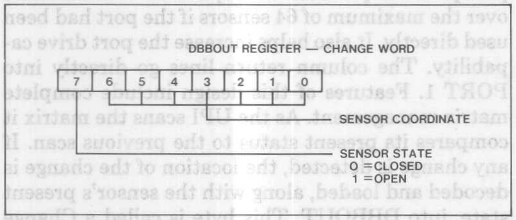

Figure 18B. Sensor Matrix Change Word Format

Internally, the matrix scanning software is programmed to run as a foreground task. This allows the timer/counter to be used by any background task although the hardware configuration leaves only 2 inputs (TEST 0 and TEST 1) plus 2 I/O port pins available. Also, to add a background task, the FIFO would have to be made smaller to accommodate the needed register and data memory space. (It would be possible however to turn the table here and make the scanning software timer/counter interrupt-driven where the timer times the scan interval.)

The data memory organization for this application is shown in Figure 19. The upper 16 bytes form the Matrix Map and store the sensor states from the previous scan; one bit for each sensor. The Change Word FIFO occupies the next 40 locations. (The top and bottom addresses of this FIFO are treated as equate variables in the program so that the FIFO size may easily be changed to accommodate the register needs of other tasks.) Register R_0 serves as a pointer into the matrix map area for comparisons and updates of the sensor status. R_1 is a general FIFO pointer. The FIFO is implemented as a circular buffer with In and Out pointer registers which are stored in R_4 and R_5 respectively. These registers are moved into FIFO pointer R_1 for actual transfers into or out of the FIFO. R_2 is the Row Select Counter. It stores the number of the row being scanned.

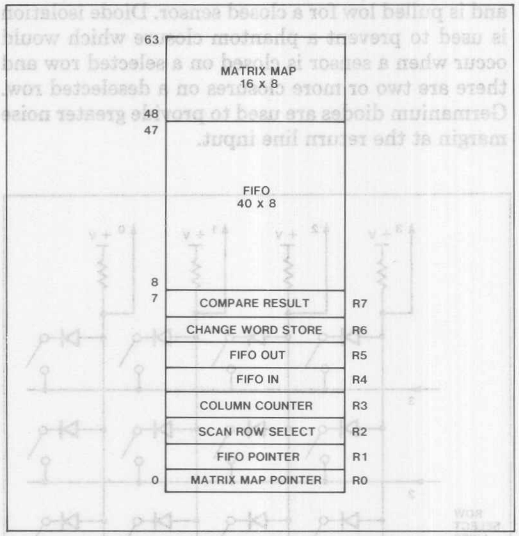

Figure 19. Sensor Matrix Data Memory Map

Register R_3 is the Column Counter. This counter is normally set to 00H; however, when a change is detected somewhere in a particular row, it is used to inspect each sensor status bit individually for a change. When a changed counter sensor bit is found, the Row Select Counter and Column Counter are combined to give the sensor's matrix coordinate. This coordinate is temporarily stored in the Change Word Store, register R_6. Register R_7 is the Compare Result. As each row is scanned, the return information is Exclusive-OR'd with the return information from the previous scan of that row. The result of this operation is stored in R_7. If R_7 is zero, there have been no changes on that row. A non-zero result indicates at least one changed sensor.

The basic program operation is shown in the flow chart of Figure 20. At RESET, the software initializes the working registers, the ports, and clears the STATUS register. To get a starting point from which to perform the sensor comparisons, the current status of the matrix is read and stored in the Matrix Map. At this point, the UPI begins looking for changed sensors starting with the first row.

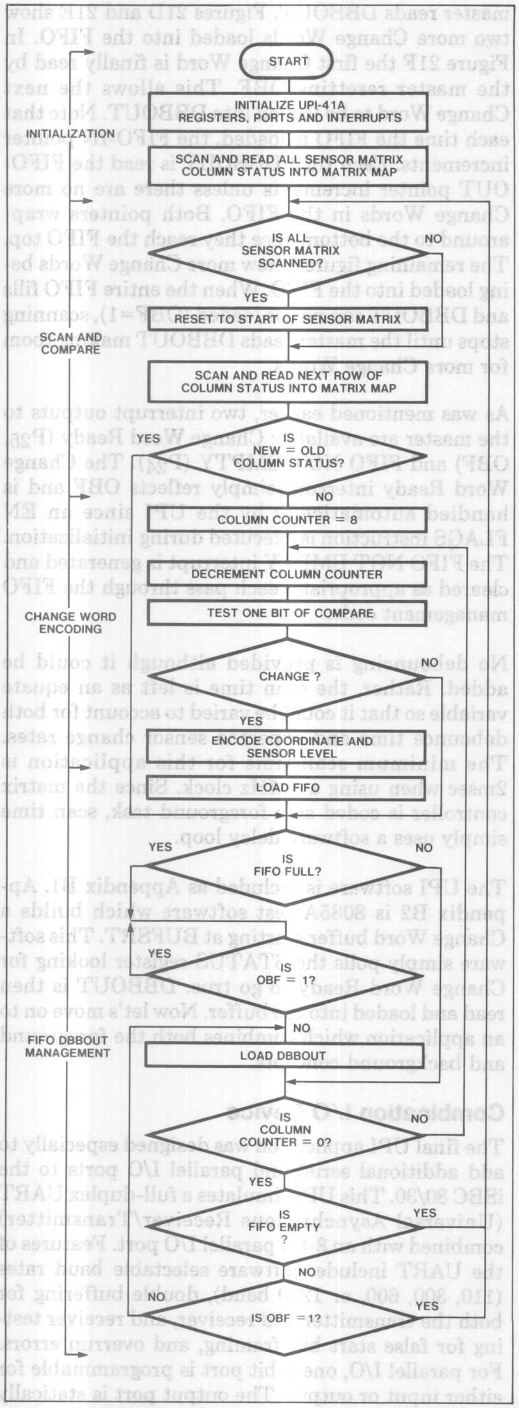

Figure 20. Sensor Matrix Controller Flow Chart

Before delving further into the flow, let's pause to describe the general format of the operation. The UPI scans the matrix one row at a time. If no changes are detected on a particular row, the UPI simply moves to the next row after checking the status of DBBOUT and the FIFO. If a change is detected, the UPI must check each bit (sensor) within the row to determine the actual sensor location. (More than one sensor on the scanned row could have changed.) Rather than test all 8 bits of the row before checking the DBBOUT and FIFO status again, the UPI performs the status check in between each of the bit tests. This ensures the fastest response to the master reading previous Change Words from DBBOUT and the FIFO.

With this general overview in mind, let's go first thru the flow chart assuming we are scanning a row where no changes have occurred. Starting at the Scan-and-Compare section, the UPI first checks if the entire matrix has been scanned. If it has, the various pointers are reset. If not, the address of the next row is placed on PORTs 20 thru 23. This selects the desired row. The state of the row is then read on PORT 1; the column return lines. This present state is compared to the previous state by retrieving the previous state from the matrix map and performing an Exclusive-OR with the present state. Since we are assuming that no change has occurred, the result is zero. No coordinate decoding is needed and the flow branches to the FIFO-DBBOUT Management section.

The FIFO-DBBOUT Management section simply maintains the FIFO and loads DBBOUT whenever Change Words are present in the FIFO and DBBOUT is clear (OBF=0). The section first tests if the FIFO is full. (If we assume our "no-change" row is the first row scanned, the FIFO obviously would not be full.) If it is, the UPI waits until OBF=0, at which point the next Change Word is retrieved from the FIFO and placed in DBBOUT. This "unfills" the FIFO making room for more Change Words. At this point, the Column Counter, R_3, is checked. For rows with no changes, the Column Counter is always zero so the test simply falls through. (We cover the case for changes shortly.) Now the FIFO is tested for being empty. If it is, there is no sense in any further tests so the flow simply goes back up to scan the next row. If the FIFO is not empty, DBBOUT is tested again through OBF. If a Change Word is in DBBOUT waiting for the master to read it, nothing can be done and the flow likewise branches up for the next row. However, if the DBBOUT is free and remembering that the previous test showed that the FIFO was not empty, DBBOUT is loaded with the next Change Word and the last two conditional tests repeat.

Now let's assume the next row contains several changed sensors. Like before, the row is selected, the return lines read, and the sensor status compared to the previous scan. Since changes have occurred, the Exclusive-OR result is now non-zero. Any 1's in the result reflect the positions of the changed sensors. This non-zero result is stored in the Compare Result register, R_7. At this point, the Column Counter is preset to 8. To determine the changed sensors' locations, the Compare Result register is shifted bit-by-bit to the left while decrementing the Column Counter. After each shift, BIT 7 of the result is tested. If it is a one, a changed sensor has been found. The Column Counter then reflected the sensor's matrix column position while the Scan Row Select register holds it row position. These registers are then combined in R_6, the Change Word Store, to form the sensor's matrix coordinate section of the Change Word. The 8th bit of the Change Word Store is coded with the sensor's present state (Figure 18). This byte forms the complete Change Word. It is loaded into the next available FIFO position. If BIT 7 of the Compare Result had been zero, that particular sensor had not changed and the coordinate decoding is not performed.

In between each shift, test, and coordinate encode (if necessary), the FIFO-DBBOUT Management is performed. It is the Column Counter test within this section that routes the flow back up to the Change Word Encoding section if the entire Compare Result (row) has not been shifted and tested.

The FIFO is implemented as a circular buffer with IN and OUT pointers (R_4 and R_5 respectively). The operations of the FIFO is best understood using an example, Figure 21. This series of figures show how the FIFO, DBBOUT, and OBF interact as changes are detected and Change Words are read by the master. The letters correspond to sequential Change Words being loaded into the FIFO. Note that the figures show only a 4×8 FIFO however, the principles are the same in the 40×8 FIFO.

Figure 21A shows the condition where no Change Words have been loaded into the FIFO or DBBOUT. In Figure 21B a change, "A", has been detected, decoded, and loaded into the FIFO at the location equal to the value of the FIFO-IN pointer. The FIFO-OUT pointer is reset to the bottom of the FIFO since it had reached the FIFO top. Now that a Change Word is in the FIFO, OBF is checked to see if DBBOUT is empty. Because OBF=0, DBBOUT is empty and the Change Word is loaded from the FIFO location pointed at by the FIFO-OUT pointer. This is shown in Figure 21C. Loading DBBOUT automatically sets OBF. OBF remains set until the master reads DBBOUT. Figures 21D and 21E show two more Change Words loaded into the FIFO. In Figure 21F the first Change Word is finally read by the master resetting OBF. This allows the next Change Word to be loaded into DBBOUT. Note that each time the FIFO is loaded, the FIFO-IN pointer increments. Each time DBBOUT is read the FIFO-OUT pointer increments unless there are no more Change Words in the FIFO. Both pointers wrap-around to the bottom once they reach the FIFO top. The remaining figures show more Change Words being loaded into the FIFO. When the entire FIFO fills and DBBOUT can not be loaded (OBF=1), scanning stops until the master reads DBBOUT making room for more Change Words.

As was mentioned earlier, two interrupt outputs to the master are available: Change Word Ready (P_{25}, OBF) and FIFO NOT EMPTY (P_{24}). The Change Word Ready interrupt simply reflects OBF and is handled automatically by the UPI since an EN FLAGS instruction is executed during initialization. The FIFO NOT EMPTY interrupt is generated and cleared as appropriate, each pass through the FIFO management code.

No debouncing is provided although it could be added. Rather, the scan time is left as an equate variable so that it could be varied to account for both debounce time and expected sensor change rates. The minimum scan time for this application is 2msec when using a 6MHz clock. Since the matrix controller is coded as a foreground task, scan time simply uses a software delay loop.

The UPI software is included as Appendix B1. Appendix B2 is 8085A test software which builds a Change Word buffer starting at BUFSRT. This software simply polls the STATUS register looking for Change Word Ready to go true. DBBOUT is then read and loaded into the buffer. Now let's move on to an application which combines both the foreground and background concepts.

Combination I/O Device

The final UPI application was designed especially to add additional serial and parallel I/O ports to the iSBC 80/30. This UPI simulates a full-duplex UART (Universal Asynchronous Receiver/Transmitter) combined with an 8-bit parallel I/O port. Features of the UART include: software selectable baud rates (110, 300, 600, or 1200 baud), double buffering for both the transmitter and receiver, and receiver testing for false start bit, framing, and overrun errors. For parallel I/O, one 8-bit port is programmable for either input or output. The output port is statically latched and the input port is sampled.

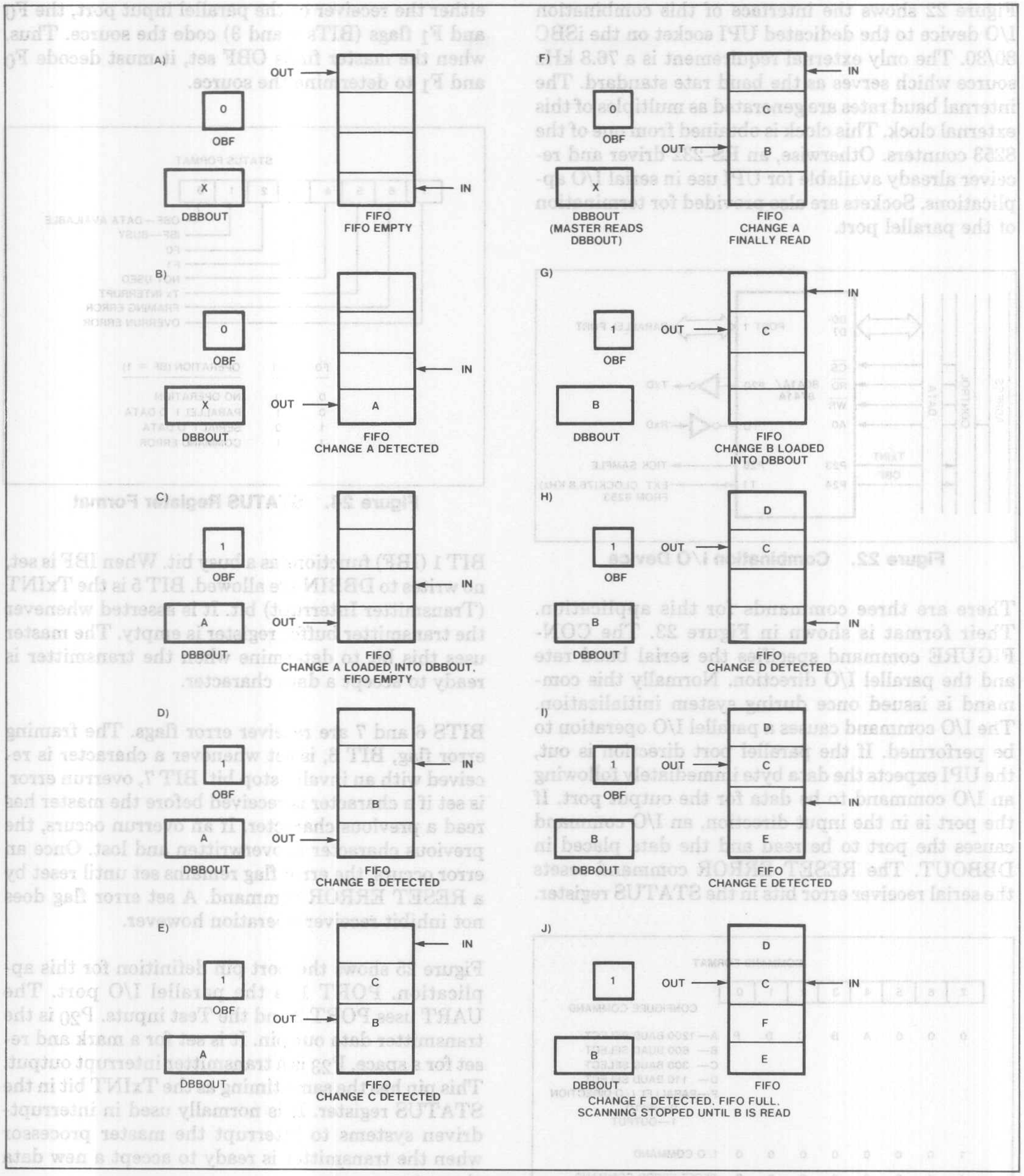

Figure 21A-J. FIFO Operation Example

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Figure 22 shows the interface of this combination I/O device to the dedicated UPI socket on the iSBC 80/30. The only external requirement is a 76.8 kHz source which serves as the baud rate standard. The internal baud rates are generated as multiples of this external clock. This clock is obtained from one of the 8253 counters. Otherwise, an RS-232 driver and receiver already available for UPI use in serial I/O applications. Sockets are also provided for termination of the parallel port.

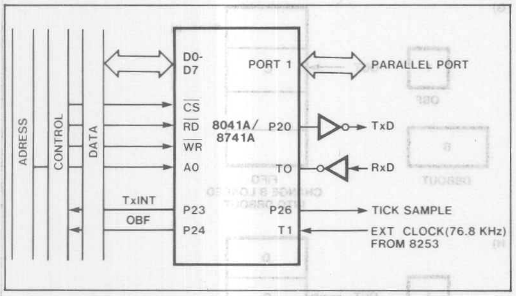

Figure 22. Combination I/O Device

There are three commands for this application. Their format is shown in Figure 23. The CONFIGURE command specifies the serial baud rate and the parallel I/O direction. Normally this command is issued once during system initialization. The I/O command causes a parallel I/O operation to be performed. If the parallel port direction is out, the UPI expects the data byte immediately following an I/O command to be data for the output port. If the port is in the input direction, an I/O command causes the port to be read and the data placed in DBBOUT. The RESET ERROR command resets the serial receiver error bits in the STATUS register.

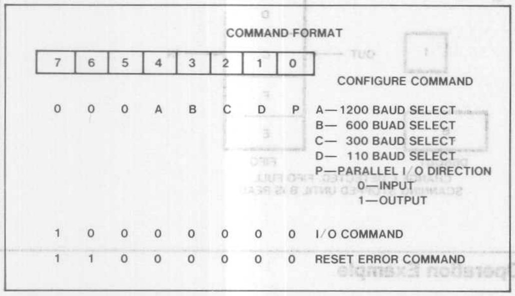

Figure 23. Combination I/O Command Format

The STATUS register format is shown in Figure 24. Looking at each bit, BIT 0 (OBF) is the DATA AVAILABLE flag. It is set whenever the UPI places data into DBBOUT. Since the data may come from either the receiver or the parallel input port, the F_0 and F_1 flags (BITs 2 and 3) code the source. Thus, when the master finds OBF set, it must decode F_0 and F_1 to determine the source.

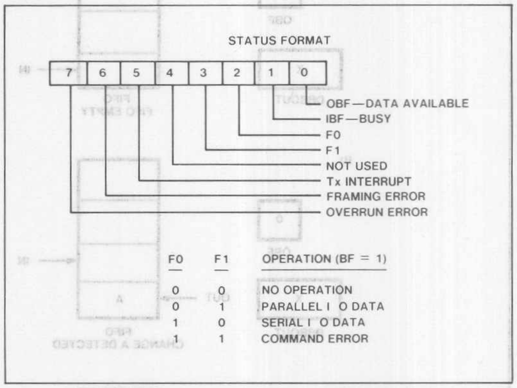

Figure 24. STATUS Register Format

BIT 1 (IBF) functions as a busy bit. When IBF is set, no writes to DBBIN are allowed. BIT 5 is the TxINT (Transmitter Interrupt) bit. It is asserted whenever the transmitter buffer register is empty. The master uses this bit to determine when the transmitter is ready to accept a data character.

BITS 6 and 7 are receiver error flags. The framing error flag, BIT 6, is set whenever a character is received with an invalid stop bit. BIT 7, overrun error, is set if a character is received before the master has read a previous character. If an overrun occurs, the previous character is overwritten and lost. Once an error occurs, the error flag remains set until reset by a RESET ERROR command. A set error flag does not inhibit receiver operation however.

Figure 25 shows the port pin definition for this application. PORT 1 is the parallel I/O port. The UART uses PORT 2 and the Test inputs. P_{20} is the transmitter data out pin. It is set for a mark and reset for a space. P_{23} is a transmitter interrupt output. This pin has the same timing as the TxINT bit in the STATUS register. It is normally used in interrupt-driven systems to interrupt the master processor when the transmitter is ready to accept a new data character.

The OBF flag is brought out on P_{24} as a master interrupt when data is available in DBBOUT. P_{26} is a diagnostic pin which pulses at four times the selected baud rate. (More about this pin later.) The receiver data input uses the TEST 0 input. One of the PORT 2 pins could have been used, however, the

PORT PIN DEFINITION

PORT	BIT	FUNCTION
1	0-7	PARALLEL I/O
2	0	Tx Data
	1	NOT USED
	2	NOT USED
	3	Tx INTERRUPT
	4	OBF INTERRUPT
	5	NOT USED
	6	NOT USED (TICK SAMPLE)
	7	NOT USED
T0		Rx DATA
T1		EXTERNAL CLOCK (76.8 kHz)

Figure 25. Combination I/O Port Definition

software can test the TEST 0 in one instruction without first reading a port.

The TEST 1 input is the baud rate external source. The UART divides this input to determine the timing needed for the selected baud rate. The input is a non-synchronous 76.8 kHz source.

Internally, when the CONFIGURE command is received and the selected baud rate is determined, the internal timer/counter is loaded with a baud rate constant and started in the event counter mode. Timer/counter interrupts are then enabled. The baud rate constant is selected to provide a counter interrupt at four times the desired baud rate. At each interrupt, both the transmitter and receiver are handled. Between interrupts, any new commands and data are recognized and executed.

As a prelude to discussing the flow charts, Figure 26 shows the register definition. Register Bank 0 serves the UART receiver and parallel I/O while Register Bank 1 handles the UART transmitter and commands. Looking at RB0 first, R_3 is the receiver status register, RxSTS. Reflected in the bits of this register is the current receiver status in sequential order. Figure 27 shows this bit definition. BIT 0 is the Rx flag. It is set whenever a possible start bit is received. BIT 1 signifies that the start bit is good and character construction should begin with the next received bit. BIT 1 is the Good Start flag. BIT 2 is the Byte Finished flag. When all data bits of a character are received, this flag is set. When all the bits, data and stop bits are received, the assembled character is loaded into the holding register (R_4 in Figure 27) BIT 3, the Data Ready flag, is set. The foreground routine which looks for commands and data continuously, looks at this bit to determine when the receiver has received a character. BITS 4 and 5 signify any error conditions for a particular character.

Address	Contents	Register	Bank
63–32	USER RAM (NOT USED)		
31	AC TEMP. STORE	R7	REGISTER BANK 1
30	COMMAND STORE	R6	
29	Tx STATUS — TxSTS	R5	
28	Tx BUFFER	R4	
27	Tx SERIALIZER	R3	
26	Tx TICK COUNTER	R2	
25	BAUD RATE CONSTANT	R1	
24	NOT USED	R0	
23–8	STACK (ONE LEVEL USED)		
7	STATUS STORE	R7	REGISTER BANK 0
6	Rx DESERIALIZER	R6	
5	Rx TICK COUNTER	R5	
4	Rx HOLDING	R4	
3	Rx STATUS—RxSTS	R3	
2	NOT USED	R2	
1	NOT USED	R1	
0	NOT USED	R0	

Figure 26. Combination I/O Register Map

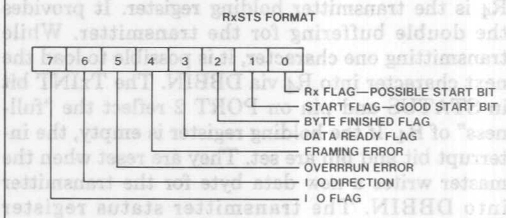

Figure 27. RxSTS Register

The parallel I/O port software uses BITS 6 and 7. BIT 6 codes the I/O direction specified by the last CONFIGURE command. BIT 7 is set whenever an I/O command is received. The foreground routine tests this bit to determine when an I/O operation has been requested by the master.

As was mentioned, R_4 is the receiver holding register. Assembled characters are held in this register until the foreground routine finds DBBOUT free, at which time the data is transferred from R_4 to DBBOUT. R_5 is the receiver tick counter. Recall that counter interrupts occur at four times the baud rate. Therefore, once a start bit is found, the receiver only needs to look at the data every four interrrupts or tick counts. R_5 holds the current tick count.

R_6 is the receiver de-serializing register. Data characters are assembled in this register. R_6 is preset to 80H when a good start bit is received. As each bit is

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sampled every four timer ticks, they are rotated into the leftmost bit of R_6. The software knows the character assembly is complete when the original preset bit rotates into the carry.

An image of the upper 4 bits of the STATUS register is stored in R_7. These bits are the TxINT, Framing and Overrun bits. This image is needed since the UPI may load the upper 4 STATUS register bits from its accumulator; however, it cannot read STATUS directly.

In Register Bank 1 (Figure 26), R1 holds the baud rate constant which is found from decoding the baud rate select bits of the CONFIGURE command. The counter is reloaded with this constant every timer tick. Like the receiver, the transmitter only needs to update the transmitter output every four ticks. R_2 holds the transmitter tick count. The value of R_2 determines which portion of the data is being transmitted; start bit, data bits, or stop bit. The transmit serializer is R_3. R_3 holds the data character as each character bit is transmitted.

R_4 is the transmitter holding register. It provides the double buffering for the transmitter. While transmitting one character, it is possible to load the next character into R_4 via DBBIN. The TxINT bit in STATUS and pin on PORT 2 reflect the "fullness" of R_4. If the holding register is empty, the interrupt bit and pin are set. They are reset when the master writes a new data byte for the transmitter into DBBIN. The transmitter status register (TxSTS) is R_5. Like RxSTS,TxSTS contains flag bits which indicate the current state of the transmitter. This flag bit format is shown in Figure 28.

TxSTS BIT 0 is the Tx flag. It is set whenever the transmitter is transmitting a character. It is set from the beginning of the start bit until the end of the stop bit. BIT 1 is the Tx request flag. This bit is set by the foreground routine when it transfers a new character from DBBIN to the Tx holding register, R_4. The transmitter software uses this flag to tell if new data is available. It is reset when the transmitter transfers the character from the holding register to the serializer.

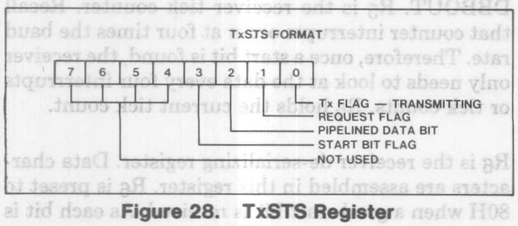

Figure 28. TxSTS Register

BIT 2 is the pipelined Tx data bit. The transmitter uses a pipelining technique which sets up the next output level in BIT 2 after processing the current timer tick. The output level is always changed at the same point after a timer tick interrupt. This technique ensures that no bit timing distortion results from different length processing paths through the receiver and transmitter routines.

BIT 3 of TxSTS is the Start Bit flag. It is set by the transmitter when the start bit space is set up in the pipelined data bit. This allows the transmitter to differentiate between the start bit and the data bits on following timer ticks.

The flow charts for this application are shown in Figures 29A–F. At reset, the INIT routine is executed which initializes the registers and port pins. After initialization, IBF and OBF are tested in MNLOOP. These flags are tested continually in this loop. If IBF is set, F_1 is tested for command or data and execution is transferred to the appropriate routine (CMD or DATA). If IBF=0, OBF is checked. If OBF=0 (DBBOUT is free), the Rx data ready and I/O flags in RxSTS are tested. If Rx data ready is set, the received data is retrieved from the Rx holding register and transferred to DBBOUT. Any error flags associated with that data are also transferred to STATUS. If the I/O flag is set and the I/O direction is input, PORT 1 is read and the data transferred to DBBOUT. In either case, F_0 and F_1 are set to indicate the data source.

If IBF is set by a command write to DBBIN, CMD reads the command and decodes the desired operation. If an I/O operation is specified, the I/O flag is set to indicate to the MNLOOP and DATA routines that an I/O operation is to be performed. If the command is a CONFIGURE command, the constant for the selected baud rate is loaded into both Baud Rate Constant register and the timer/counter. The timer/counter is started in the event counter mode and timer/counter interrupts are enabled. In addition, the I/O port is initialized to all 1's if the I/O direction bit specifies an input port. If the command is a RESET ERROR command, the two error flags in STATUS are cleared.

If the IBF flag is set by a data write, the DATA routine reads DBBIN and places the data in the appropriate place. If the I/O flag is set, the data is for the output port so the port is loaded. If the I/O flag is reset, the data is for the UART transmitter. Data for the transmitter resets the TxINT bit and pin plus sets the Tx request flag in TxSTS. The data is transferred to the Tx holding register, R_4.

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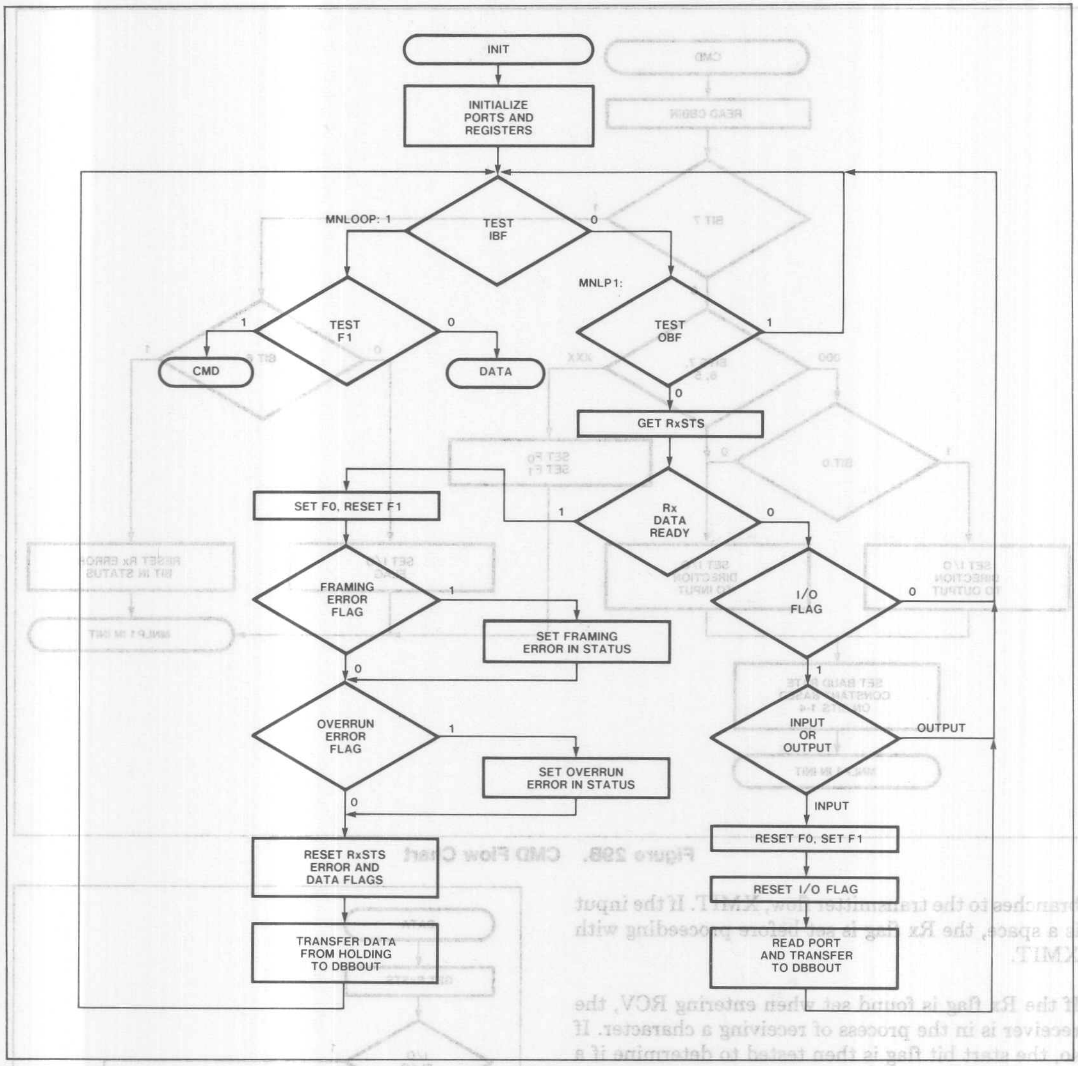

Figure 29A. INIT Flow Chart

Once a CONFIGURE command is received and the counter started, timer/counter interrupts start occurring at four times the selected baud rate. These interrupts cause a vector to the TIMINT routine, Figure 29D. A 76.8 kHz counter input provides a 13.02 μs counter resolution. Since it requires several UPI instruction cycles to reload the counter, the counter is set to two counts less than the desired baud rate and the counter is reloaded in TIMINT synchronous with the second low-going transition after the interrupt. Once the counter is reloaded, an output port (P_{26}) is toggled to give an external indication of internal counter interval. This is a helpful diagnostic feature. After the tick sample output, the pipelined transmitter data in TxSTS is output to the TxD pin. Although this occurs every timer tick, the pipelined data is changed only every fourth tick.

The receiver is now handled, Figure 29E. The Rx flag in RxSTS is examined to see if the receiver is currently in the process of receiving a character. If it is not, the RxD input is tested for a space condition which might indicate a possible start bit. If the input is a mark, no start bit is possible and execution

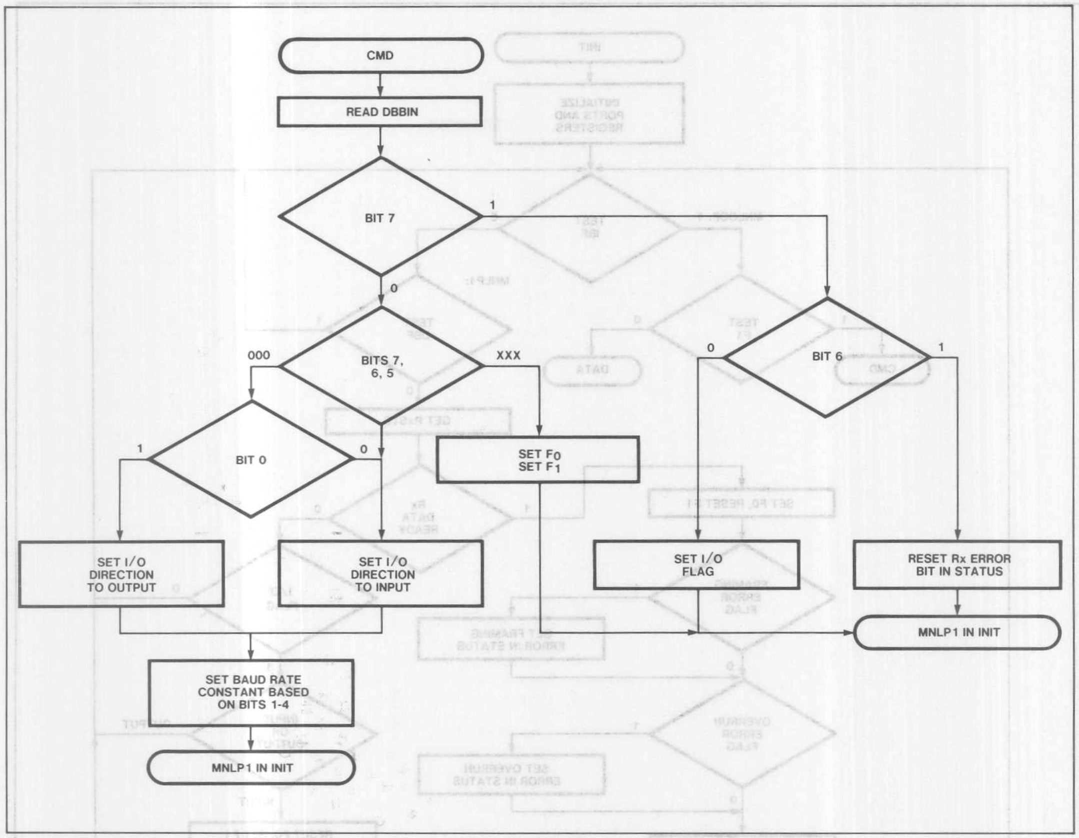

Figure 29B. CMD Flow Chart

branches to the transmitter flow, XMIT. If the input is a space, the Rx flag is set before proceeding with XMIT.

If the Rx flag is found set when entering RCV, the receiver is in the process of receiving a character. If so, the start bit flag is then tested to determine if a good start bit was received. The Rx tick counter is initialized to 4 and the Rx deserializer is set to 80H. A mark indicates a bad start bit; the Rx flag is reset to abort the reception.

If the start bit flag is set, the program is somewhere in the middle of the received character. Since the data should be sampled every fourth timer tick, the tick counter is decremented and tested for zero. If non-zero no sample is needed and execution continues with XMIT. If zero, the tick counter is reset to four. Now the byte finished flag is tested to determine if the data sample is a data or stop bit. If reset, the sample is a data bit. The sample is done and the new bit rotated into the Rx deserializer. If this rotate

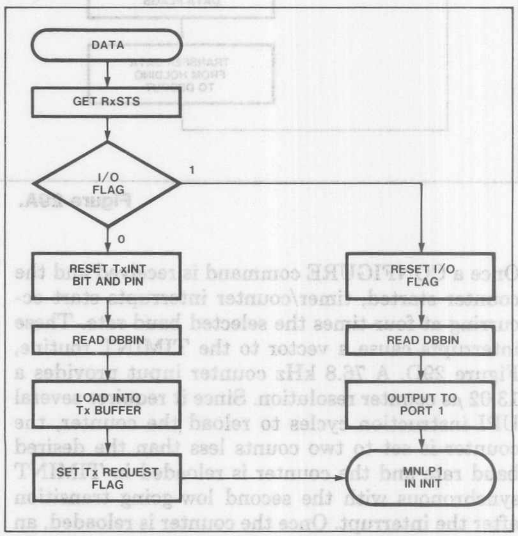

Figure 29C. Data Flow Chart

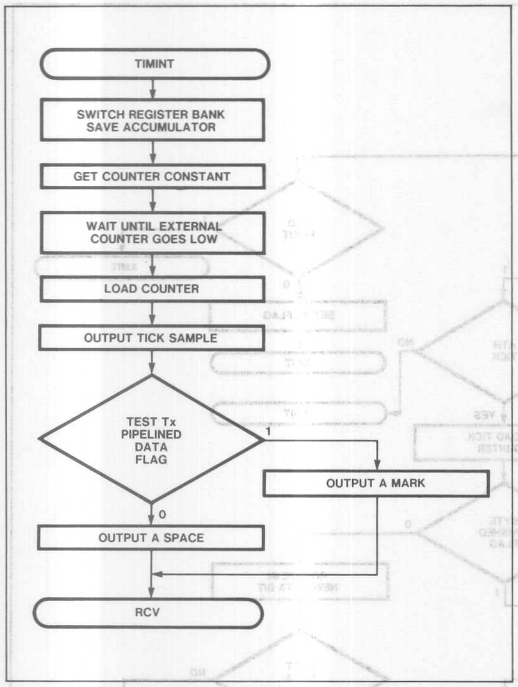

Figure 29D. TIMINT Flow Chart

sets the carry, that data bit was the last so the byte finished flag is set. If the carry is reset, the data bit is not the last so execution simply continues with XMIT.

Had the byte finished flag been set, this sample is for the stop bit. The RxD input is tested and if a space, the framing error flag is set. Otherwise, it is reset. Next, the Rx data ready flag is tested. If it is set, the master has not read the previous character so the overrun error flag is set. Then the Rx data ready flag is set and the received data character is transferred into the Rx holding register. The Rx, start bit, and byte finished flags are reset to get ready for the next character.

Execution of the transmitter routine, XMIT, follows the receiver, Figure 29F. The transmitter starts by checking the start bit flag in TxSTS. Recall that the actual transmit data is output at the beginning of the timer routine. The start bit flag indicates whether the current timer tick interrupt started the start bit. If it is set, the pipelined data output earlier in the routine was the start of the start bit so the flag is reset and the Tx tick counter is initialized. Nothing else is done this timer tick so the routine returns to the foreground.

If the start bit flag is reset, the Tx tick counter is incremented and tested. The test is performed modulo 4. If the counter mod 4 is not zero, it has not been four ticks since the transmitter was handled last so the routine simply returns. If the counter mod 4 is zero, it is time to handle the transmitter and the Tx flag is tested.

The Tx flag indicates whether the transmitter is active. If the transmitter is inactive, no character is currently being transmitted so the Tx request flag is tested to see if a new character is waiting in the Tx buffer. If no character is waiting (Tx request flag=0), the Tx interrupt pin and bit are set before returning to the foreground. If there is a character waiting, it is retrieved from the buffer and placed in the Tx serializer. The Tx request flag is reset while the Tx and start bit flags are set. A space is placed in the Tx pipelined data bit so a start bit will be output on the next tick. Since the Tx buffer is now empty, the Tx interrupt bit and pin are set to indicate the availability of the buffer to the master. The routine then returns to the foreground.

If the tick counter mod 4 is zero and the Tx flag indicates the transmitter is in the middle of a character, the tick counter is checked to see what transmitter operation is needed. If the counter is 28H (40D), all data bits plus the stop bits are complete. The character is therefore done and the Tx flag is reset. If the counter is 24H (36D), the data bits are complete and the next output should be a mark for the stop bit so a mark is loaded into the Tx pipelined data bit.

If neither of the above conditions are met for the counter, the transmitter is some place in the data field, so the next data bit is rotated out of the Tx serializer into the pipelined data bit. The next tick outputs this bit.

At this point the program execution is returned to the foreground.

That completes the discussion of the combination I/O device flow charts. The UPI software listing is shown in Appendix C1. Appendix C2 is example 8085A driver software.

Several observations concerning the drivers are appropriate. Notice that since the receiver and input port of the UPI use the OBF flag and interrupt output, the interrupt and flag are cleared when the master reads DBBOUT. This is not true for the transmitter. There is always some time after a master write of new transmitter data before the transmitter bit and pin are cleared. Thus in an interrupt-driven system, edge-sensitive interrupts should be

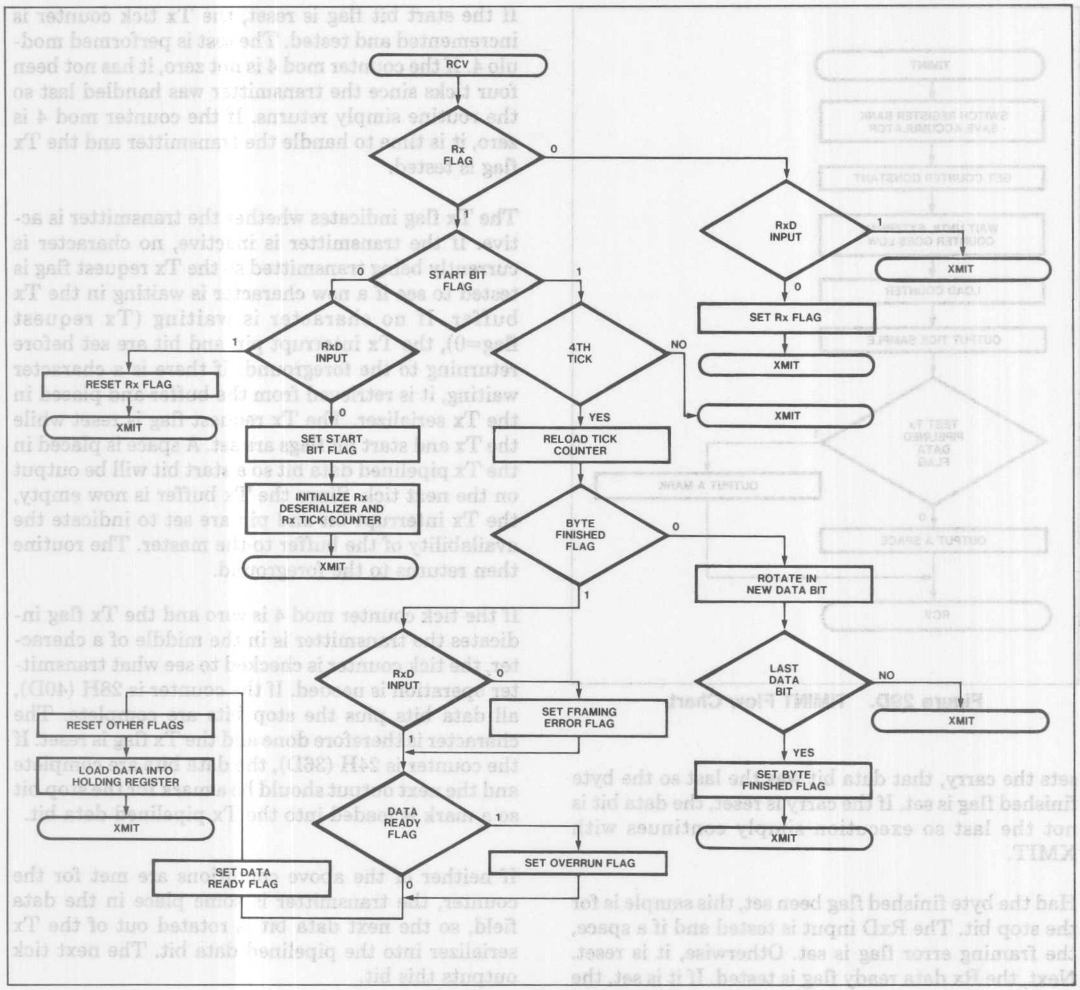

Figure 29E. RCV Flow Chart

used. For polled-systems, the software must wait after writing new data for IBF=0 before re-examining the Tx interrupt flag in STATUS.

Notice that this application uses none of the user data memory above Register Bank 1 and only 361 bytes of program memory. This leaves the door open for many improvements. Improvements that come to mind are increased buffering of the transmit or received data, modem control pins, and parallel port handshaking inputs.

This completes our discussion of specific UPI applications. Before concluding, let's look briefly at two debug techniques used during the development of these applications that you might find useful in your own designs.

DEBUG TECHNIQUES

Since the UPI is essentially a single-chip microcomputer, the classical data, address, and control buses are not available to the outside world during normal operation. This fact normally makes debugging a UPI design difficult; however, certain "tricks" can be included in the UPI software to ease this task.

If a UPI is handling multiple tasks, it is usually easier to code and debug each task individually. This is fairly standard procedure. Since each task usually utilizes only a subset of the total number of I/O pins,

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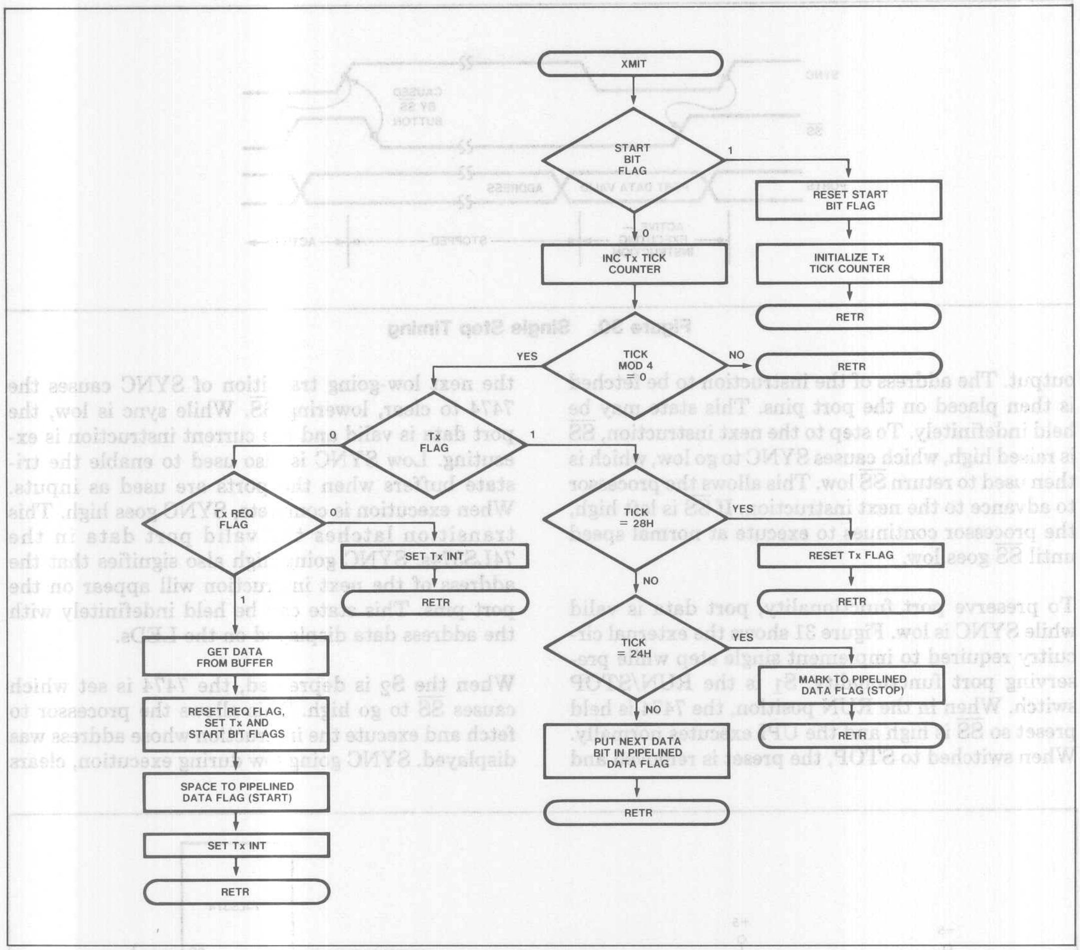

Figure 29F. XMIT Flow Chart

coding only one task leaves some I/O pins free. Port output instructions can then be added in the task code being debugged which toggle these unused pins to determine which section of task code is being executed at any particular time. The task can also be made to "wait" at various points by using an extra pin as an input and adding code to loop until a particular input condition is met.

One example of using an extra pin as an output is included in the combination serial/parallel device code. During initial development the receiver was not receiving characters correctly. Since this could be caused by incorrect sampling, three lines of code were added to toggle BIT 6 of PORT 2 at each tick of the sample clock. This code is at lines 184 and 185 of the listing. Thus by looking at the location of the tick sample pulse with respect to the received bit, the UPI sampling interval can be observed. The tick sample time was incorrect and the code was modified accordingly. Similar techniques could be applied at other locations in the program.

The EPROM version of the UPI (8741A) also contains another feature to aid in debug: the capability to single step thru a program. The user may step thru the program instruction-by-instruction. The address of the next instruction to be fetched is available on PORT 1 and the lower 2 bits of PORT 2. Figure 30 shows the timing used in the discussion below. When the single step input, $\overline{SS}$, is brought low, the internal processor responds by stopping during the fetch portion of the next instruction. This action is acknowledged by the processor raising the SYNC

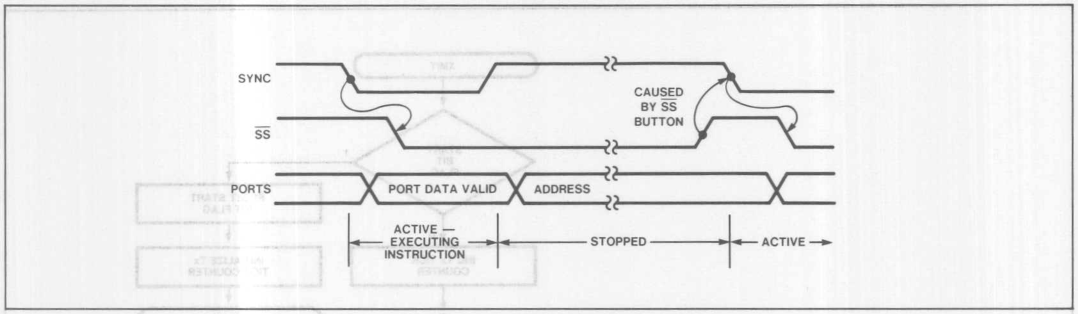

Figure 30. Single Step Timing

output. The address of the instruction to be fetched is then placed on the port pins. This state may be held indefinitely. To step to the next instruction, $\overline{SS}$ is raised high, which causes SYNC to go low, which is then used to return $\overline{SS}$ low. This allows the processor to advance to the next instruction. If $\overline{SS}$ is left high, the processor continues to execute at normal speed until $\overline{SS}$ goes low.

To preserve port functionality, port data is valid while SYNC is low. Figure 31 shows the external circuitry required to implement single step while preserving port functionality. S_1 is the RUN/STOP switch. When in the RUN position, the 7474 is held preset so $\overline{SS}$ is high and the UPI executes normally. When switched to STOP, the preset is removed and the next low-going transition of SYNC causes the 7474 to clear, lowering $\overline{SS}$. While sync is low, the port data is valid and the current instruction is executing. Low SYNC is also used to enable the tri-state buffers when the ports are used as inputs. When execution is complete, SYNC goes high. This transition latches the valid port data in the 74LS374s. SYNC going high also signifies that the address of the next instruction will appear on the port pins. This state can be held indefinitely with the address data displayed on the LEDs.

When the S_2 is depressed, the 7474 is set which causes $\overline{SS}$ to go high. This allows the processor to fetch and execute the instruction whose address was displayed. SYNC going low during execution, clears

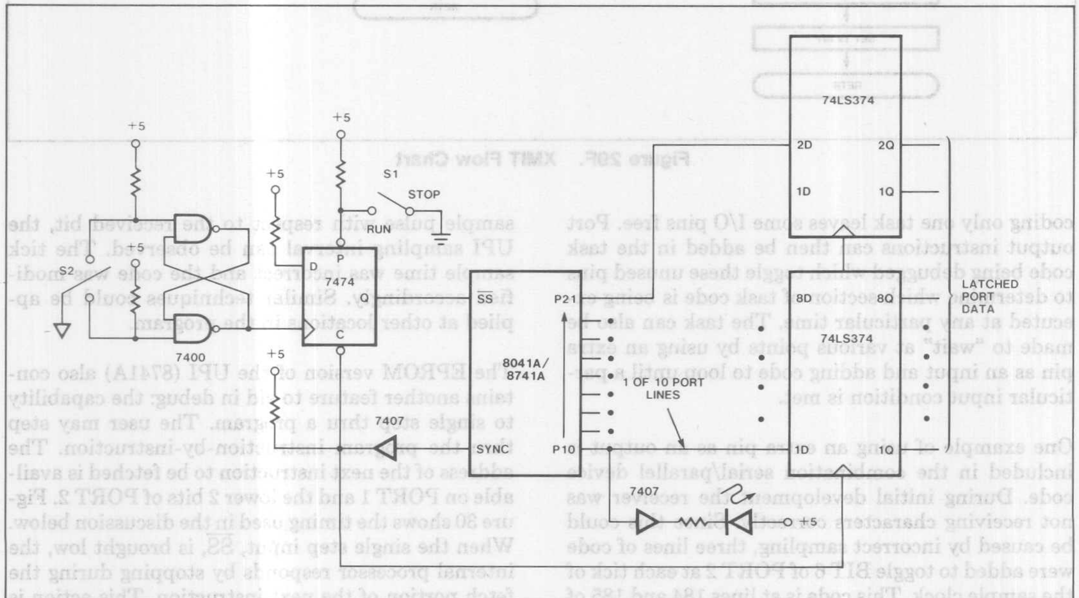

Figure 31. Single Step External Circuitry

the 7474 lowering $\overline{SS}$. Thus the processor again stops when execution is complete and the next fetch is started.

All UPI functions continue to operate while single stepping (the processor is actually executing NOPs internally while stopped). Both IBF and timer/counter interrupts can be serviced. The only change is that the interval timer is prescaled on single stepped instructions and, of course, will not indicate the correct intervals in real time. The total number of instruction which would have been executed during a given interval is the same however.

The single step circuitry can be used to step through a complete program; however, this might be a time-consuming job if the program is long or if only a portion is to be examined. The circuitry could easily be modified to incorporate the output toggling technique to determine when to run and stop. If you would like to step thru a particular section of code, an extra port pin could replace switch S_1. Extra instructions would then be added to lower the port when entering the code section and raise the port when exiting the section. The program would then stop when that section of code is reached allowing it to be stepped through. At the end of the section, the program would execute at normal speed.

CONCLUSION

Well, that's it. Machine readable (floppy disk or paper tape) source listings of UPI software for these applications are available in Insite, the Intel library of user-donated programs. Also available in Insite are the source listings for some of Intel's pre-programmed UPI products.

For information about Insite, write to:
Insite
Intel Corp.
3065 Bowers Ave.
Santa Clara, Ca 95051

APPENDIX A

```
:F1:ASM48 :F3:LED PRINT(:LP:) NOOBJECT


ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0          PAGE    1


 LOC  OBJ          LINE        SOURCE STATEMENT

$MOD41A
;       **********************************************
;       *    UPI-41A 8-DIGIT LED DISPLAY CONTROLLER    *
;       **********************************************
;
;
;
;THIS PROGRAM USES THE UPI-41A AS A LED DISPLAY CONTROLLER
;WHICH SCANS AND REFRESHES EIGHT SEVEN-SEGMENT LED DISPLAYS.
;THE CHARACTERS ARE DEFINED BY INPUT FROM A MASTER CPU IN THE
;FORM OF ONE EIGHT BIT WORD PER DIGIT-CHARACTER SELECTION.
;
;
;
;*********************************************************************
;
;REGISTER DEFINITIONS:
;       REGISTER                RB1                           RBO
;       --------                ---                           ---
;       R0              DISPLAY MAP POINTER                 NOT USED
;       R1              NOT USED                            NOT USED
;       R2              DATA WORD AND CHARACTER STORAGE     NOT USED
;       R3              DIGIT COUNTER                       NOT USED
;       R4              NOT USED                            NOT USED
;       R5              NOT USED                            NOT USED
;       R6              NOT USED                            NOT USED
;       R7              ACCUMULATOR STORAGE                 NOT USED
;*********************************************************************
;
;PORT PIN DEFINITIONS:
;       PIN             PORT 1 FUNCTION         PORT 2 FUNCTION
;       ---             ---------------         ---------------
;       P0-7            SEGMENT DRIVER CONTROL  DIGIT DRIVER CONTROL
;
$EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0                 PAGE    2

 LOC  OBJ         LINE         SOURCE STATEMENT

;***************************************************************************
;DISPLAY DATA WORD BIT DEFINITION:
;         BIT                 FUNCTION
;         ---                 --------
;         0-4                 CHARACTER SELECT
;         5-7                 DIGIT SELECT
;
;CHARACTER SELECT:
;                   D4   D3   D2   D1   D0   CHARACTER
;                   0    0    0    0    0       0
;                   0    0    0    0    1       1
;                   0    0    0    1    0       2
;                   0    0    0    1    1       3
;                   0    0    1    0    0       4
;                   0    0    1    0    1       5
;                   0    0    1    1    0       6
;                   0    0    1    1    1       7
;                   0    1    0    0    0       8
;                   0    1    0    0    1       9
;                   0    1    0    1    0       A
;                   0    1    0    1    1       B
;                   0    1    1    0    0       C
;                   0    1    1    0    1       D
;                   0    1    1    1    0       E
;                   0    1    1    1    1       F
;                   1    0    0    0    0       .
;                   1    0    0    0    1       G
;                   1    0    0    1    0       H
;                   1    0    0    1    1       I
;                   1    0    1    0    0       J
;                   1    0    1    0    1       L
;                   1    0    1    1    0       N
;                   1    0    1    1    1       O
;                   1    1    0    0    0       P
;                   1    1    0    0    1       R
;                   1    1    0    1    0       T
;                   1    1    0    1    1       U
;                   1    1    1    0    0       Y
;                   1    1    1    0    1       -
;                   1    1    1    1    0       /
;                   1    1    1    1    1       "BLANK"
;
;DIGIT SELECT:
;                   D7   D6   D5    DIGIT NUMBER
;                   0    0    0          1
;                   0    0    1          2
;                   0    1    0          3
;                   0    1    1          4
;                   1    0    0          5
;                   1    0    1          6
;                   1    1    0          7
;                   1    1    1          8
;***************************************************************************
$EJECT
```

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```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0                PAGE     3

 LOC  OBJ          LINE        SOURCE STATEMENT

                     90 ;************************************************************************
                     91 ;                           EQUATES
                     92 ;THE FOLLOWING CODE DESIGNATES "TIME" AS A VARIABLE. THIS
                     93 ;ADJUSTS THE AMOUNT OF CYCLES THE TIMER COUNTS BEFORE
                     94 ;A TIMER INTERRUPT OCCURS AND REFRESHES THE DISPLAY. APPROXIMATELY
                     95 ;50 TIMES PER SECOND.
 FFF1                96 TIME     EQU     -0FH        ;TIMER VALUE 2.5MSEC
                     97 ;************************************************************************
                     98 ;                      INTERRUPT BRANCHING
                     99 ;THIS PORTION OF MEMORY IS DEDICATED FOR USE OF RESET AND
                    100 ;INTERRUPT BRANCHING. WHEN THE INTERRUPTS ARE ENABLED THE
                    101 ;CODE AT THE FOLLOWING DESIGNATED SPOTS ARE EXECUTED WHEN A
                    102 ;RESET OR A INTERRUPT OCCURS.
 0000               103          ORG     0           ;
 0000 0409          104          JMP     START       ;RESET
 0002 00            105          NOP                 ;
 0003 0436          106          JMP     INPUT       ;IBF INTERRUPT
 0005 00            107          NOP                 ;
 0006 00            108          NOP                 ;
 0007 041D          109          JMP     DISPLA      ;TIMER INTERRUPT
                    110 ;************************************************************************
                    111 ;                      INITIALIZATION
                    112 ;THE FOLLOWING CODE SETS UP THE UPI-41 AND DISPLAY HARDWARE
                    113 ;INTO OPERATIONAL FORMAT. THE DISPLAY IS TURNED OFF, THE DISPLAY
                    114 ;MAP IS FILLED WITH "BLANK" CHARACTERS, THE TIMER SET AND THE
                    115 ;INTERRUPTS ARE ENABLED.
                    116 ;
 0009 D5            117 START:   SEL     RB1
 000A 8A08          118          ORL     P2,#08H     ;TURN DIGIT DRIVERS OFF
 000C B838          119          MOV     R0,#38H     ;DISPLAY MAP POINTER, BOTTOM OF DISPLAY MAP
 000E 23FF          120 BLKMAP:  MOV     A,#0FFH     ;FF="BLANK"
 0010 A0            121          MOV     @R0,A       ;BLANK TO DISPLAY MAP
 0011 18            122          INC     R0          ;INCREMENT DISPLAY MAP POINTER
 0012 F8            123          MOV     A,R0        ;DISPLAY MAP POINTER TO ACCUMULATOR
 0013 B20E          124          JB5     BLKMAP      ;BLANK DISPLAY MAP TILL FILLED
 0015 BB00          125          MOV     R3,#00H     ;SET DIGIT COUNTER TO 0
 0017 23F1          126          MOV     A,#TIME     ;TIMER VALUE
 0019 62            127          MOV     T,A         ;LOAD TIMER
 001A 55            128          STRT    T           ;START TIMER
 001B 25            129          EN      TCNTI       ;ENABLE TIMER INTERRUPT
 001C 05            130          EN      I           ;ENABLE IBF INTERRUPT
                    131 ;************************************************************************
                    132 ;                       USER PROGRAM
                    133 ;A USERS PROGRAM WOULD INITIALIZE AT THIS POINT. THE FOLLOWING
                    134 ;CODE IS UND CONCLUDED WITH
                    135 ;SYNC CHARACTERS (0AAH).   A CHECKSUM BYTE IMMEDIATELY PRECEEDS THE
                    136 ;FINAL SYNC.   WHEN READING, THE CONTROLLE*************************************
                    137 $EJECT
```

```
LOC  OBJ         LINE        SOURCE STATEMENT

                  138 ;************************************************************************
                  139 ;                               DISPLAY ROUTINE
                  140 ; THIS PORTION OF THIS PROGRAM IS AN INTERRUPT ROUTINE WHICH IS
                  141 ;ACTED UPON WHEN THE TIMER COUNT IS COMPLETED. THE ROUTINE UPDATES
                  142 ;ONE DISPLAY DIGIT FROM THE DISPLAY MAP PER INTERRUPT SEQUENTIALLY,
                  143 ;THUS EIGHT TIMER INTERRUPTS WILL HAVE REFRESHED THE ENTIRE DISPLAY.
                  144 ;REGISTER BANK 1 IS SELECTED AND THE ACCUMULATOR IS SAVED UPON
                  145 ;ENTERING THE ROUTINE. ONCE THE DISPLAY HAS BEEN REFRESHED THE TIMER
                  146 ;IS RESET AND THE ACCUMULATOR AND PRE-INTERRUPT REGISTER BANK IS RESTORED.
                  147 ;
001D D5           148 DISPLA: SEL     RB1             ;REGISTER BANK 1
001E AF           149         MOV     R7,A            ;SAVE ACCUMULATOR
001F 8A08         150         ORL     P2,#08H         ;TURN DIGIT DRIVERS OFF
0021 FB           151         MOV     A,R3            ;DIGIT COUNTER TO ACCUMULATOR
0022 4338         152         ORL     A,#38H          ;"OR" TO GET DISPLAY MAP ADDRESS
0024 A8           153         MOV     R0,A            ;DISPLAY MAP POINTER
0025 F0           154         MOV     A,@R0           ;GET CHARACTER FROM DISPLAY MAP
0026 39           155         OUTL    P1,A            ;OUTPUT CHARACTER TO SEGMENT DRIVERS
0027 FB           156         MOV     A,R3            ;DIGIT COUNTER VALUE TO ACCUMULATOR
0028 3A           157         OUTL    P2,A            ;OUTPUT TO DIGIT DRIVERS
0029 1B           158         INC     R3              ;INCREMENT DIGIT COUNTER
002A D307         159         XRL     A,#07H          ;CHECK IF AT LAST DIGIT
002C 9630         160         JNZ     SETIME          ;RESET TIMER IN NOT LAST DIGIT
002E BB00         161         MOV     R3,#00H         ;RESET DIGIT COUNTER
0030 23F1         162 SETIME: MOV     A,#TIME         ;TIMER VALUE
0032 62           163         MOV     T,A             ;LOAD TIMER
0033 55           164         STRT    T               ;START TIMER
0034 FF           165         MOV     A,R7            ;RESTORE ACCUMULATOR
0035 93           166         RETR                    ;RETURN
                  167 ;************************************************************************
                  168 $EJECT
```

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```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0          PAGE    5

 LOC  OBJ          SOURCE STATEMENT

               ;
               ;************************************************************************
               ;                INPUT CHARACTER AND DIGIT ROUTINE
               ; THIS PORTION OF THE PROGRAM IS AN INTERRUPT ROUTINE WHICH
               ;IS ACTED UPON WHEN THE IBF BIT IS SET. THE ROUTINE GETS THE
               ;DISPLAY DATA WORD FROM THE DBB AND DEFINES BOTH THE DIGIT AND
               ;THE CHARACTER TO BE DISPLAYED. THIS IS DONE BY MEANS OF A
               ;CHARACTER LOOP-UP TABLE AND A DISPLAY MAP FOR DIGIT AND CHARACTER
               ;LOCATION. SPECIAL CONSIDERATION IS TAKEN FOR A DECIMAL POINT WHICH IS
               ;SIMPLY ADDED TO THE EXISTING CHARACTER IN THE DISPLAY MAP. REGISTER
               ;BANK 1 IS SELECTED AND THE ACCUMULATOR IS SAVED UPON ENTERING
               ;THE ROUTINE. ONCE THE DATA WORD HAS BEEN FULLY DEFINED THE ACCUMULATOR
               ;AND THE PRE-INTERRUPT REGISTER BANK IS RESTORED.
               ;
0036 D5        INPUT:  SEL     RB1         ;REGISTER BANK 1
0037 AF                MOV     R7,A        ;SAVE ACCUMULATOR
0038 22                IN      A,DBB       ;GET DATA
0039 AA                MOV     R2,A        ;SAVE DATA WORD
003A 47                SWAP    A           ;DEFINE DIGIT LOCATION
003B 77                RR      A           ;
003C 5307              ANL     A,#07H      ;
003E 4338              ORL     A,#38H      ;
0040 A8                MOV     R0,A        ;DIGIT LOCATION IN DIGIT POINTER
0041 FA                MOV     A,R2        ;SAVED DATA WORD TO ACCUMULATOR
0042 531F              ANL     A,#1FH      ;DEFINE CHARACTER LOOK-UP-TABLE LOC.
0044 E3                MOVP3   A,@A        ;GET CHARACTER
0045 AA                MOV     R2,A        ;SAVE CHARACTER
0046 D37F              XRL     A,#7FH      ;IS CHARACTER DECIMAL POINT
0048 C64E              JZ      DPOINT      ;
004A FA                MOV     A,R2        ;SAVED CHARACTER TO ACCUMULATOR
004B A0                MOV     @R0,A       ;CHARACTER TO DISPLAY MAP
004C 0451              JMP     RETURN      ;
004E FA        DPOINT: MOV     A,R2        ;SAVED CHARACTER TO ACCUMULATOR
004F 50                ANL     A,@R0       ;"AND" WITH OLD CHARACTER
0050 A0                MOV     @R0,A       ;BACK TO DISPLAY MAP
0051 FF        RETURN: MOV     A,R7        ;RESTORE ACCUMULATOR
0052 93                RETR
               ;************************************************************************
               $EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0          PAGE    6

 LOC  OBJ        LINE        SOURCE STATEMENT

                  208 ;**********************************************************************
                  209 ;                          LOOK-UP TABLE
                  210 ; THIS LOOK-UP TABLE ORIGINATES IN PAGE 3 OF THE UPI-41 PROGRAM
                  211 ;MEMORY. IT IS USED TO DEFINE THE CORRECT LEVEL OF EACH SEGMENT
                  212 ;AND DECIMAL POINT FOR A SELECTED CHARACTER FROM THE INPUT ROUTINE.
                  213 ;INVERSE LOGIC IS USED BECAUSE OF THE SPECIFIC DRIVER CIRCUITRY, THUS
                  214 ;A 1 ON A GIVEN SEGMENT MEANS IT IS OFF AND A 0 MEANS IT IS ON.
                  215 ;
                  216                              ;*******SEGMENTS********
0300              217         ORG     300H        ;DP  G  F  E  D  C  B  A
0300 C0           218 CH0:    DB      0C0H        ;1   1  0  0  0  0  0  0
0301 F9           219 CH1:    DB      0F9H        ;1   1  1  1  1  0  0  1
0302 A4           220 CH2:    DB      0A4H        ;1   0  1  0  0  1  0  0
0303 B0           221 CH3:    DB      0B0H        ;1   0  1  1  0  0  0  0
0304 99           222 CH4:    DB      99H         ;1   0  0  1  1  0  0  1
0305 92           223 CH5:    DB      92H         ;1   0  0  1  0  0  1  0
0306 82           224 CH6:    DB      82H         ;1   0  0  0  0  0  1  0
0307 F8           225 CH7:    DB      0F8H        ;1   1  1  1  1  0  0  0
0308 80           226 CH8:    DB      80H         ;1   0  0  0  0  0  0  0
0309 98           227 CH9:    DB      98H         ;1   0  0  1  1  0  0  0
030A 88           228 CHA:    DB      88H         ;1   0  0  0  1  0  0  0
030B 83           229 CHB:    DB      83H         ;1   0  0  0  0  0  1  1
030C C6           230 CHC:    DB      0C6H        ;1   1  0  0  0  1  1  0
030D A1           231 CHD:    DB      0A1H        ;1   0  1  0  0  0  0  1
030E 86           232 CHE:    DB      86H         ;1   0  0  0  0  1  1  0
030F 8E           233 CHF:    DB      8EH         ;1   0  0  0  1  1  1  0
0310 7F           234 CHDP:   DB      7FH         ;0   1  1  1  1  1  1  1
0311 C2           235 CHG:    DB      0C2H        ;1   1  0  0  0  0  1  0
0312 89           236 CHH:    DB      89H         ;1   0  0  0  1  0  0  1
0313 FB           237 CHI:    DB      0FBH        ;1   1  1  1  1  0  1  1
0314 E1           238 CHJ:    DB      0E1H        ;1   1  1  0  0  0  0  1
0315 C7           239 CHL:    DB      0C7H        ;1   1  0  0  0  1  1  1
0316 AB           240 CHN:    DB      0ABH        ;1   0  1  0  1  0  1  1
0317 A3           241 CHO:    DB      0A3H        ;1   0  1  0  0  0  1  1
0318 8C           242 CHP:    DB      8CH         ;1   0  0  0  1  1  0  0
0319 AF           243 CHR:    DB      0AFH        ;1   0  1  0  1  1  1  1
031A 87           244 CHT:    DB      87H         ;1   0  0  0  0  1  1  1
031B C1           245 CHU:    DB      0C1H        ;1   1  0  0  0  0  0  1
031C 91           246 CHY:    DB      91H         ;1   0  0  1  0  0  0  1
031D BF           247 CHDASH: DB      0BFH        ;1   0  1  1  1  1  1  1
031E FD           248 CHAPOS: DB      0FDH        ;1   1  1  1  1  1  0  1
031F FF           249 BLANK:  DB      0FFH        ;1   1  1  1  1  1  1  1
                  250 ;**********************************************************************
                  251         END

USER SYMBOLS
BLANK  031F   BLKMAP 000E   CH0    0300   CH1    0301   CH2    0302   CH3    0303   CH4    0304   CH5    0305
CH6    0306   CH7    0307   CH8    0308   CH9    0309   CHA    030A   CHAPOS 031E   CHB    030B   CHC    030C
CHD    030D   CHDASH 031D   CHDP   0310   CHE    030E   CHF    030F   CHG    0311   CHH    0312   CHI    0313
CHJ    0314   CHL    0315   CHN    0316   CHO    0317   CHP    0318   CHR    0319   CHT    031A   CHU    031B
CHY    031C   DISPLA 001D   DPOINT 004E   INPUT  0036   RETURN 0051   SETIME 0030   START  0009   TIME   FFF1

ASSEMBLY COMPLETE,   NO ERRORS
```

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```
:F1:ASM48 :F3:SENSOR NOOBJECT PRINT(:LP:)


ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0              PAGE    1

 LOC   OBJ          LINE         SOURCE STATEMENT

$MOD41A
;
;         ************************************************
;         *     UPI-41A SENSOR MATRIX CONTROLLER         *
;         ************************************************
;
;         THIS PROGRAM USES THE UPI-41A AS A SENSOR MATRIX CONTROLLER.
;IT HAS MONITORING CAPABILITIES OF UP TO 128 SENSORS.  THE COORDINATE
;AND SENSOR STATUS OF EACH DETECTED CHANGE IS AVAILABLE TO THE MASTER
;MICROPROCESSOR IN A SINGLE BYTE.  A 40X8 FIFO QUEUE IS PROVIDED FOR
;DATA BUFFERING.  BOTH HARDWARE OR POLLED INTERRUPT METHODS CAN BE USED
;TO NOTIFY THE MASTER OF A DETECTED SENSOR CHANGE.
;
;**********************************************************************
;
;REGISTER DEFINITIONS:
;         REGISTER                RBO                     RBI
;         --------                ---                     ---
;            R0           MATRIX MAP POINTER          NOT USED
;            R1           FIFO POINTER                NOT USED
;            R2           SCAN ROW SELECT             NOT USED
;            R3           COLUMN COUNTER              NOT USED
;            R4           FIFO-IN                     NOT USED
;            R5           FIFO-OUT                    NOT USED
;            R6           CHANGE WORD                 NOT USED
;            R7           COMPARE                     NOT USED
;
;**********************************************************************

;PORT PIN DEFINITIONS:
;
;PIN         PORT 1 FUNCTION        PIN          PORT 2 FUNCTION
;---         ---------------        ---          ---------------
;P0-7        COLUMN LINE INPUTS     P0-3         ROW SELECT OUTPUTS
;                                   P4           FIFO NOT EMPTY INTERRUPT
;                                   P5           OBF INTERRUPT
;                                   P6-7         NOT USED
;
;**********************************************************************

$EJECT
```


AFN-01536A

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0                PAGE    2

LOC  OBJ         LINE        SOURCE STATEMENT

                 ;*********************************************************************
                 ;
                 ;CHANGE WORD BIT DEFINITION:
                 ;
                 ;                    BIT                  FUNCTION
                 ;                    ---                  --------
                 ;                    D0-6                 SENSOR COORDINATE
                 ;                    D7                   SENSOR STATUS
                 ;
                 ;*************************************************************************
                 ;
                 ;STATUS REGISTER BIT DEFINITION:
                 ;
                 ;                    BIT                  FUNCTION
                 ;                    ---                  --------
                 ;                    D0                   OBF
                 ;                    D1-3                 IBF, F0, F1 (NOT USED)
                 ;                    D4                   FIFO NOT EMPTY
                 ;                    D5-7                 USED DEFINED (NOT USED)
                 ;
                 ;*************************************************************************
                 ;
                 ;                           EQUATES
                 ;
                 ;THE FOLLOWING CODE DESIGNATES THREE VARIABLES, SCANTM, FIFOBA
                 ;AND FIFOTA.  SCANTM ADJUSTS THE LENGTH OF A DELAY BETWEEN
                 ;SCANNING SWITCH.  THIS SIMULATES DEBOUNCE FUNCTIONS.  FIFOBA
                 ;IS THE BOTTOM ADDRESS OF THE FIFO.  FIFOTA IS THE TOP ADDRESS
                 ;OF THE FIFO.  THIS MAKES IT POSSIBLE TO HAVE A FIFO 3 TO 40
                 ;BYTES IN LENGTH.
                 ;
                 ;*********************************************************************
                 ;
000F              SCANTM  EQU    0FH               ;SCAN TIME ADJUST
0008              FIFOBA  EQU    08H               ;FIFO BOTTOM ADDRESS
002F              FIFOTA  EQU    2FH               ;FIFO TOP ADDRESS

                  $EJECT
```

AFN-01536A

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0                PAGE     3

 LOC  OBJ         LINE        SOURCE STATEMENT

                  ;*********************************************************************
                  ;
                  ;                          INITIALIZATION
                  ;
                  ;THE PROGRAM STARTS AT THE FOLLOWING CODE UPON RESET.  WITHIN
                  ;THIS INITIALIZATION SECTION THE REGISTERS THAT MAINTAIN THE MATRIX
                  ;MAP,FIFO AND ROW SCANNING ARE SET UP.  PORT 1 IS SET HIGH FOR USE
                  ;AS AN INPUT PORT FOR THE COLUMN STATUS.  BIT 4 OF STATUS REGISTER IS
                  ;WRITTEN TO CONVEY A FIFO EMPTY CONDITION.  THE INITIAL COLUMN STATUS
                  ;OF ALL THE ROWS IN THE SENSOR MATRIX IS THEN READ INTO THE MATRIX
                  ;MAP.  ONCE THE MATRIX MAP IS FILLED THE OBF INTERRUPT (PORT 2-4) IS
                  ;ENABLED.
                  ;
                  ;*********************************************************************

0000                      ORG     0
0000 B83F         INITMX: MOV     R0,#3FH      ;MATRIX MAP POINTER REGISTER,TOP ADDRESS
0002 BA0F                 MOV     R2,#0FH      ;SCAN ROW SELECT REGISTER,TOP ROW
0004 BC08                 MOV     R4,#FIFOBA   ;FIFO INPUT ADDRESS REGISTER,BOTTOM OF FIFO
0006 BD2F                 MOV     R5,#FIFOTA   ;FIFO OUTPUT ADDRESS REGISTER,TOP OF FIFO
0008 89FF                 ORL     P1,#0FFH     ;INITIALIZE PORT 1 HIGH FOR INPUTS
000A 2300                 MOV     A,#00H       ;INITIALIZE STATUS REGISTER, FIFO EMPTY
000C 90                   MOV     STS,A        ;WRITE TO STATUS REGISTER, BITS 4-7
000D FA           FILLMX: MOV     A,R2         ;SCAN ROW SELECT TO ACCUMULATOR
000E 3A                   OUTL    P2,A         ;OUTPUT SCAN ROW SELECT TO PORT 2
000F 09                   IN      A,P1         ;INPUT COLUMN STATUS PORT 1
0010 A0                   MOV     @R0,A        ;LOAD MATRIX MAP WITH COLUMN STATUS
0011 FA                   MOV     A,R2         ;CHECK SCAN ROW SELECT REGISTER VALUE FOR 0
0012 C618                 JZ      OBFINT       ;IF 0 ENABLE OBF INTERRUPT
0014 C8                   DEC     R0           ;DECREMENT TO NEXT MATRIX MAP ADDRESS
0015 CA                   DEC     R2           ;DECREMENT TO SCAN NEXT ROW
0016 040D                 JMP     FILLMX       ;FILL NEXT MATRIX MAP ADDRESS
0018 BA10         OBFINT: MOV     R2,#10H      ;BIT 4 HIGH IN ROW SCAN SELECT REGISTER
001A FA                   MOV     A,R2         ;ROW SCAN SELECT VALUE TO ACCUMULATOR
001B 3A                   OUTL    P2,A         ;INITIALIZE PORT 2, BIT 4 FOR "EN FLAGS"
001C F5                   EN      FLAGS        ;ENABLE OBF INTERRUPT PORT 2, BIT 4

                  $EJECT
```

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```
LOC  OBJ         SOURCE STATEMENT

                 ;*************************************************************************
                 ;
                 ;                         SCAN AND COMPARE
                 ;
                 ;THE FOLLOWING CODE IS THE SCAN AND COMPARE SECTION OF THE PROGRAM.
                 ;UPON ENTERING THIS SECTION A CHECK IS MADE TO SEE IF THE ENTIRE MATRIX
                 ;HAS BEEN SCANNED.  IF SO THE REGISTERS THAT MAINTAIN THE MATRIX MAP AND ROW
                 ;SCANNING ARE RESET TO THE BEGINNING OF THE SENSOR MATRIX.  IF THE ENTIRE
                 ;MATRIX HASNT BEEN SCANNED THE REGISTERS INCREMENT TO SCAN THE NEXT ROW.
                 ;FROM THIS POINT ON THE ROW SCAN SELECT REGISTER IS USED FOR TWO FUNCTIONS.
                 ;BITS 0-3 FOR SCANNING AND BITS 4 AND 5 FOR THE EXTERNAL INTERRUPTS.  THUSLY
                 ;ALL USAGE OF THE REGISTERS IS DONE BY LOGICALLY MASKING IT SO AS TO ONLY
                 ;AFFECT THE FUNCTION DESIRED.  ONCE THE REGISTERS ARE RESET, ONE ROW OF THE
                 ;SENSOR MATRIX IS SCANNED.  A DELAY IS EXECUTED TO ADJUST FOR SCAN TIME
                 ;(DEBOUNCE).  A BYTE OF COLUMN STATUS IS THEN READ INTO THE MATRIX MAP.
                 ;AT THE TIME THE NEW COLUMN STATUS IS COMPARED TO THE OLD.  THE RESULT IS
                 ;STORED IN THE COMPARE REGISTER.  THE PROGRAM IS THEN ROUTED ACCORDING TO
                 ;WHETHER OR NOT A CHANGE WAS DETECTED.
                 ;
                 ;*************************************************************************

001D FA          ADJREG: MOV     A,R2           ;SCAN ROW SELECT TO ACCUMULATOR
001E 530F                ANL     A,#0FH         ;CHECK FOR 0 SCAN VALUE ONLY,NOT INTERRUPT
0020 C626                JZ      RSETRG         ;IF 0 RESET REGISTERS
0022 C8                  DEC     R0             ;DECREMENT MATRIX MAP POINTER
0023 CA                  DEC     R2             ;DECREMENT SCAN ROW SELECT
0024 042C                JMP     SCANMX         ;SCAN MATRIX
0026 B83F        RSETRG: MOV     R0,#3FH        ;RESET MATRIX MAP POINTER REGISTER,TOP ADDRESS
0028 FA                  MOV     A,R2           ;SCAN ROW SELECT TO ACCUMULATOR
0029 430F                ORL     A,#0FH         ;RESET SCAN ROW SELECT,NO INTERRUPT CHANGE
002B AA                  MOV     R2,A           ;SCAN ROW SELECT REGISTER
002C FA          SCANMX: MOV     A,R2           ;SCAN ROW SELECT TO ACCUMULATOR
002D 3A                  OUTL    P2,A           ;OUTPUT SCAN ROW SELECT TO PORT 2
002E BB0F                MOV     R3,#SCANTM     ;SET DELAY FOR OUTPUT SCAN TIME
0030 EB30        DELAY2: DJNZ    R3,DELAY2      ;DELAY
0032 09                  IN      A,P1           ;INPUT COLUMN STATUS FROM PORT 1 TO ACCUMULATOR
0033 20                  XCH     A,@R0          ;STORE NEW COLUMN STATUS SAVE OLD IN ACCUMULATOR
0034 D0                  XRL     A,@R0          ;COMPARE OLD WITH NEW COLUMN STATUS
0035 AF                  MOV     R7,A           ;SAVE COMPARE RESULT IN COMPARE REGISTER
0036 C669                JZ      CHFFUL         ;IF THE SAME, CHECK IF FIFO IS FULL

                 $EJECT
```

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```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0              PAGE    5

LOC  OBJ         LINE        SOURCE STATEMENT

                  159 ;***********************************************************************
                  160 ;
                  161 ;                        CHANGE WORD ENCODING
                  162 ;
                  163 ;THE FOLLOWING CODE IS THE CHANGE WORD ENCODING SECTION.  THIS
                  164 ;SECTION IS ONLY EXECUTED IF A CHANGE WAS DETECTED.  THE COLUMN COUNTER
                  165 ;IS SET AND DECREMENTED TO DESIGNATE EACH OF THE 8 COLUMNS.  THE COMPARE
                  166 ;REGISTER IS LOOKED AT ONE BIT AT A TIME TO FIND THE EXACT LOCATION OF
                  167 ;THE CHANGE(S).  WHEN A CHANGE IS FOUND IT IS ENCODED BY GIVING IT A
                  168 ;COORDINATE FOR ITS LOCATION.  THIS IS DONE BY COMBINING THE PRESENT VALUE
                  169 ;IN THE ROW SCAN SELECT REGISTER AND THE COLUMN COUNTER.  THE ACTUAL STATUS
                  170 ;OF THAT SENSOR IS ESTABLISHED BY LOOKING AT THE CORRESPONDING BYTE IN
                  171 ;THE MATRIX MAP.  THIS STATUS IS COMBINED WITH THE COORDINATE TO ESTABLISH
                  172 ;THE CHANGE WORD.  THE CHANGE WORD IS THEN STORED IN THE CHANGE WORD REGISTER.
                  173 ;
                  174 ;**********************************************************************
                  175 ;
0038 BB08         176          MOV    R3,#08H      ;SET COLUMN COUNTER REGISTER TO 8
003A CB           177 RRLOOK:  DEC    R3           ;DECREMENT COLUMN COUNTER
003B F0           178          MOV    A,@R0        ;COLUMN STATUS TO ACCUMULATOR
003C 77           179          RR     A            ;ROTATE COLUMN STATUS RIGHT
003D A0           180          MOV    @R0,A        ;ROTATED COLUMN STATUS BACK TO MATRIX MAP
003E FF           181          MOV    A,R7         ;COMPARE REGISTER VALUE TO ACCUMULATOR
003F 77           182          RR     A            ;ROTATE COMPARE VALUE RIGHT
0040 AF           183          MOV    R7,A         ;ROTATED COMPARE VALUE TO COMPARE REGISTER
0041 F245         184          JB7    ENCODE       ;TEST BIT 7 IF CHANGE DETECTED ENCODE CHANGE WORD
0043 0469         185          JMP    CHFFUL       ;IF NO CHANGE IS DETECTED CHECK FOR FIFO FULL
0045 FA           186 ENCODE:  MOV    A,R2         ;SCAN ROW SELECT TO ACCUMULATOR  0000XXXX
0046 530F         187          ANL    A,#0FH       ;ROTATE ONLY SCAN VALUE
0048 E7           188          RL     A            ;ROTATE LEFT                     000XXXX0
0049 E7           189          RL     A            ;ROTATE LEFT                     00XXXX00
004A E7           190          RL     A            ;ROTATE LEFT                     0XXXX000
004B 4B           191          ORL    A,R3         ;ESTABLISH MATRIX COORDINANT     0XXXXXXX
                  192                               ;(OR) COLUMN COUNTER VALUE WITH ACCUMULATOR
004C AE           193          MOV    R6,A         ;SAVE COORDINANT IN CHANGE WORD REGISTER
004D F0           194          MOV    A,@R0        ;COLUMN STATUS FROM MATRIX MAP TO ACCUMULATOR
004E 5380         195          ANL    A,#80H       ;O ALL BITS BUT BIT 7
0050 4E           196          ORL    A,R6         ;(OR) SENSOR STATUS WITH COORDINATE FOR COMPLETED CHANGE WORD
0051 AE           197          MOV    R6,A         ;SAVE CHANGE WORD                XXXXXXXX
                  198
                  199 $EJECT
```

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```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0              PAGE     6

LOC  OBJ          LINE        SOURCE STATEMENT

                  ;************************************************************************
                  ;
                  ;                          FIFO-DBBOUT MANAGEMENT
                  ;
                  ;THE FOLLOWING CODE IS THE FIFO-DBBOUT MANAGEMENT SECTION OF THE
                  ;PROGRAM.  THIS SECTION TAKES AN ENCODED CHANGE WORD AND LOADS IT INTO
                  ;THE FIFO. THE FIFO NOT EMPTY INTERRUPT IS THEN SET AND THE FIFO-IN
                  ;POINTER GETS UPDATED. A FIFO FULL CONDITION IS THEN CHECKED FOR AND
                  ;ROUTED ACCORDINGLY.  IF BOTH THE FIFO AND OBF HAVE CHANGE WORDS THE
                  ;PROGRAM LOCKS UP UNTIL THIS HAS CHANGED.  IF THE FIFO ISNT FULL COLUMN
                  ;COUNTER= 0, FIFO EMPTY AND OBF CONDITIONS ARE CHECKED.  THE FIFO-OUT
                  ;POINTER IS SET AND DBBOUT IS LOADED IF THE FIFO ISNT EMPTY AND OBF ISNT
                  ;SET.  IF THIS ISNT THE SITUATION, PROGRAM FLOW IS ROUTED BACK TO THE
                  ;THE SCAN AND COMPARE SECTION TO SCAN THE NEXT ROW.
                  ;
                  ;************************************************************************
                  ;
0052 FC           LOADFF: MOV    A,R4           ;FIFO INPUT ADDRESS TO ACCUMULATOR
0053 A9                   MOV    R1,A           ;FIFO POINTER USED FOR INPUT
0054 FE                   MOV    A,R6           ;CHANGE WORD TO ACCUMULATOR
0055 A1                   MOV    @R1,A          ;LOAD FIFO AT FIFO INPUT ADDRESS
0056 2310         STATNE: MOV    A,#10H         ;BIT 4 FOR FIFO NOT EMPTY
0058 90                   MOV    STS,A          ;WRITE TO STATUS REGISTER, FIFO NOT EMPTY
0059 8A20         INTRH1: ORL    P2,#20H        ;FIFO NOT EMPTY INTERRUPT PORT 2-5 HIGH
005B FA                   MOV    A,R2           ;ROW SCAN SELECT TO ACCUMULATOR
005C 4320                 ORL    A,#20H         ;SAVE INTERRUPT, NO CHANGE TO SCAN VALUE
005E AA                   MOV    R2,A           ;ROW SCAN SELECT REGISTER
005F 232F         ADJFIN: MOV    A,#FIFOTA      ;FIFO TOP ADDRESS TO ACCUMULATOR
0061 DC                   XRL    A,R4           ;COMPARE WITH CURRENT FIFO INPUT ADDRESS
0062 C667                 JZ     RSFFIN         ;IF THE SAME RESET FIFO INPUT REGISTER
0064 1C                   INC    R4             ;NEXT FIFO INPUT ADDRESS
0065 0469                 JMP    CHFFUL         ;CHECK FIFO FULL
0067 BC08         RSFFIN: MOV    R4,#FIFOBA     ;RESET FIFO INPUT REGISTER,BOTTOM OF FIFO
0069 FC           CHFFUL: MOV    A,R4           ;FIFO INPUT ADDRESS TO ACCUMULATOR
006A DD                   XRL    A,R5           ;COMPARE INPUT WITH OUTPUT FIFO ADDRESS
006B 967D                 JNZ    CHCNTR         ;IF NOT SAME CHECK COLUMN COUNTER VALUE
006D 866D         CHOBF1: JOBF   CHOBF1         ;IF OBF IS 1 THEN CHECK OBF
006F 232F         ADJFOT: MOV    A,#FIFOTA      ;FIFO TOP ADDRESS TO ACCUMULATOR
0071 DD                   XRL    A,R5           ;COMPARE TOP TO OUTPUT FIFO ADDRESS
0072 C677                 JZ     RSFFOT         ;IF THE SAME RESET FIFO OUTPUT REGISTER
0074 1D                   INC    R5             ;NEXT FIFO OUTPUT ADDRESS
0075 0479                 JMP    LOADDB         ;LOAD DBBOUT
0077 BD08         RSFFOT: MOV    R5,#FIFOBA     ;RESET FIFO OUTPUT ADDRESS TO BOTTOM OF FIFO
0079 FD           LOADDB: MOV    A,R5           ;OUTPUT FIFO ADDRESS TO ACCUMULATOR
007A A9                   MOV    R1,A           ;FIFO POINTER USED FOR OUTPUT
007B F1                   MOV    A,@R1          ;CHANGE WORD TO ACCUMULATOR
007C 02                   OUT    DBB,A          ;CHANGE WORD TO DBBOUT
007D FB           CHCNTR: MOV    A, R3          ;COLUMN COUNTER TO ACCUMULATOR
007E 963A                 JNZ    RRLOOK         ;IF NOT 0 FINISH CHANGE WORD ENCODING
0080 2308         CHFFEM: MOV    A,#FIFOBA      ;FIFO BOTTOM ADDRESS TO ACCUMULATOR

                  $EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V3.0          PAGE    7

 LOC  OBJ          LINE         SOURCE STATEMENT

 0082 DC           252          XRL    A,R4        ;COMPARE FIFO INPUT ADDRESS WITH FIFO BOTTOM ADD
 0083 C68C         253          JZ     ADJFEM      ;IF THE SAME, ADJUST TO CHECK FOR FIFO EMPTY
 0085 FC           254          MOV    A,R4        ;FIFO INPUT ADDRESS TO ACCUMULATOR
 0086 07           255          DEC    A           ;DECREMENT FIFO INPUT ADDRESS IN ACCUMULATOR
 0087 DD           256          XRL    A,R5        ;COMPARE INPUT TO OUTPUT FIFO ADDRESSES
 0088 C691         257          JZ     STATMT      ;IF SAME,WRITE STATUS REGISTER FOR FIFO EMPTY
 008A 049C         258          JMP    CHOBF2      ;CHECK OBF
 008C 232F         259 ADJFEM:  MOV    A,#FIFOTA   ;FIFO TOP ADDRESS TO ACCUMULATOR
 008E DD           260          XRL    A,R5        ;COMPARE TOP TO OUTPUT FIFO ADDRESS
 008F 969C         261          JNZ    CHOBF2      ;IF NOT SAME THEN FIFO IS NOT EMPTY, CHECK OBF
 0091 2300         262 STATMT:  MOV    A,#00H      ;CLEAR BIT 0 FOR FIFO EMPTY
 0093 90           263          MOV    STS,A       ;WRITE TO STATUS REGISTER
 0094 9ADF         264 INTRLO:  ANL    P2,#0DFH    ;FIFO EMPTY, INTERRUPT PORT 2-5 LOW
 0096 FA           265          MOV    A,R2        ;SCAN ROW SELECT TO ACCUMULATOR
 0097 53DF         266          ANL    A,#0DFH     ;SAVE INTERRUPT, NO CHANGE TO SCAN VALUE
 0099 AA           267          MOV    R2,A        ;SCAN ROW SELECT REGISTER
 009A 041D         268          JMP    ADJREG      ;ADJUST REGISTERS
 009C 861D         269 CHOBF2:  JOBF   ADJREG      ;IF OBF=1 THEN ADJUST REGISTERS
 009E 046F         270          JMP    ADJFOT      ;ADJUST FIFO OUT ADDRESS TO LOAD DBBOUT
                   271
                   272          END

USER SYMBOLS
ADJFEM 008C   ADJFIN 005F   ADJFOT 006F   ADJREG 001D   CHCNTR 007D   CHFFEM 0080   CHFFUL 0069   CHOBF1 006D
CHOBF2 009C   DELAY2 0030   ENCODE 0045   FIFOBA 0008   FIFOTA 002F   FILLMX 000D   INITMX 0000   INTRH1 0059
INTRLO 0094   LOADDB 0079   LOADFF 0052   OBFINT 0018   RRLOOK 003A   RSETRG 0026   RSFFIN 0067   RSFFOT 0077
SCANMX 002C   SCANTM 000F   STATMT 0091   STATNE 0056

ASSEMBLY COMPLETE,    NO ERRORS
```

AFN-01536A

PROGRAMMABLE KEYBOARD INTERFACE

- **Simultaneous Keyboard and Display Operations**
- **Interface Signals for Contact and Capacitive Coupled Keyboards**
- **128-Key Scanning Logic**
- **10.7msec Matrix Scan Time for 128 Keys and 6MHz Clock**
- **Eight Character Keyboard FIFO**
- **N-Key Rollover with Programmable Error Mode on Multiple New Closures**
- **Sixteen or Eight Character Seven-Segment Display Interface**
- **Right or Left Entry Display RAM**
- **Depress/Release Mode Programmable**
- **Interrupt Output on Key Entry**

This application is a general purpose programmable keyboard and display interface device designed for use with 8-bit microprocessors like the MCS-80 and MCS-85. The keyboard portion can provide a scanned interface to 128-key contact or capacitive-coupled keyboards. The keys are fully debounced with N-key rollover and programmable error generation on multiple new key closures. Keyboard entries are stored in an 8-character FIFO with overrun status indication when more than 8 characters are entered. Key entries set an interrupt request output to the master CPU.

The display portion of the UPI-41A provides a scanned display interface for LED, incandescent and other popular display technologies. Both numeric displays and simple indicators may be used. The UPI-41A has a 16×4 display RAM which can be

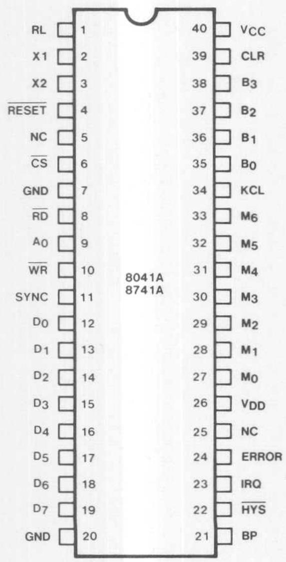


Figure 1. Pin Configuration

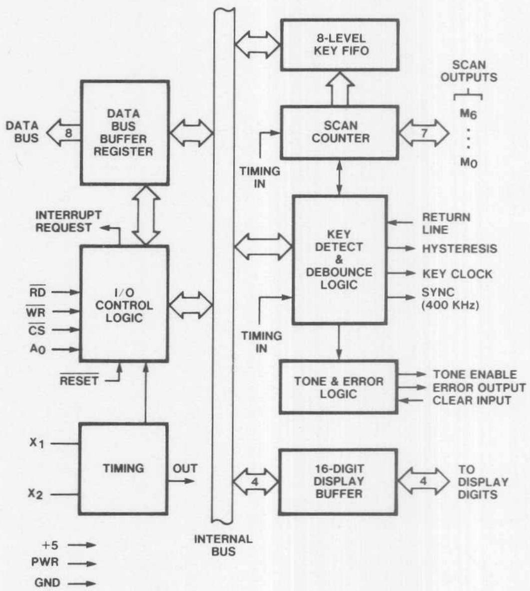


Figure 2. Block Diagram

loaded or interrogated by the CPU. Both right entry calculator and left entry typewriter display formats are possible. Both read and write of the display RAM can be done with auto increment of the display RAM address.

ORDERING INFORMATION:

This part may be ordered as an 8041A with ROM code number 8278. The source code is available through Insite.

Throughout this application of the UPI-41A, it will be referred to by its ROM code number, 8278. The 8278 is packaged in a 40-pin DIP. The following is a brief functional description of each pin.

PRINCIPLES OF OPERATION

The following is a description of the major elements of the Programmable Keyboard/Display interface device. Refer to the block diagram in Figure 1.

I/O Control and Data Buffers

The I/O control section uses the $\overline{CS}$, A_0, $\overline{RD}$, and $\overline{WR}$ lines to control data flow to and from the various internal registers and buffers (see Table 2). All data flow to and from the 8278 is enabled by $\overline{CS}$. The 8-bits of information being transferred by the CPU is identified by A_0. A logic one means information is command or status. A logic zero means the information is data. $\overline{RD}$ and $\overline{WR}$ determine the direction of data flow through the Data Bus Buffer (DBB). The

Table 1. Pin Description

Signal	Pin. No.	Type	Name and Function
D_0-D_7	12-19	I/O	**Data Bus:** Three-state, bi-directional data bus lines used to transfer data and commands between the CPU and the 8278.
$\overline{WR}$	10	I	**Write:** Write strobe which enables the master CPU to write data and commands between the CPU and the 8278.
$\overline{RD}$	8	I	**Read:** Read strobe which enables the master CPU to read data and status from the 8278 internal registers.
$\overline{CS}$	6	I	**Chip Select:** Chip select input used to enable reading and writing to the 8278.
A_0	9	I	**Control/Data:** Address input used by the CPU to indicate control or data.
$\overline{RESET}$	4	I	**Reset:** A low signal on this pin resets the 8278.
X_1, X_2	2,3	I	**Freq. Reference Inputs:** Inputs for crystal, L-C or external timing signal to determine internal oscillator frequency.
IRQ	23	O	**Interrupt Request:** Interrupt Request Output to the master CPU. In the keyboard mode the IRQ line goes low with each FIFO read and returns high if there is still information in the FIFO or an ERROR has occurred.
M_0–M_6	27-33	O	**Matrix Scan Lines:** Matrix scan outputs. These outputs control a decoder which scans the key matrix columns and the 16 display digits. Also, the Matrix scan outputs are used to multiplex the return lines from the key matrix.
RL	1	I	**Keyboard Return Line:** Input from the multiplexer which indicates whether the key currently being scanned is closed.
$\overline{HYS}$	22	O	**Hysteresis:** Hysteresis output to the analog detector. (Capacitive keyboard configuration). A "0" means the key currently being scanned has already been recorded.
KCL	34	O	**Key Clock:** Key Clock output to the analog detector (capacitive keyboard configuration) used to reset the detector before scanning a key.
SYNC	11	O	**Output Clock:** High frequency (400 kHz) output signal used in the key scan to detect a closed key (capacitive keyboard configuration).
B_0-B_3	35-38	O	**Display Outputs:** These four lines contain binary coded decimal display information synchronized to the keyboard column scan. The outputs are for multiplexed digital displays.
ERROR	24	O	**Error Signal:** This line is high whenever two new key closures are detected during a single scan or when too many characters are entered into the keyboard FIFO. It is reset by a system RESET pulse or by a "1" input on the CLR pin or by the CLEAR ERROR command.
CLR	39	I	**Clear Error:** Input used to clear an ERROR condition in the 8278.
BP	21	O	**Tone Enable:** Tone enable output. This line is high for 10ms following a valid key closure; it is set high and remains high during an ERROR condition.
V_{CC}, V_{DD}	40,26	I	**Power:** +5 volt power input: +5V ± 10%.
GND	20,7	I	**Ground:** Signal ground.

DBB register is a bi-directional 8-bit buffer register which connects the internal 8278 bus buffer register to the external bus. When the chip is not selected ($\overline{CS}$ = 1) the DBB is in the high impedance state. The DBB acts as an input when ($\overline{RD}$, $\overline{WR}$, $\overline{CS}$) = (1, 0, 0) and an output when ($\overline{RD}$, $\overline{WR}$, $\overline{CS}$) = (0, 1, 0).

Table 2. I/O Control and Data Buffers

$\overline{CS}$	A_0	$\overline{WR}$	$\overline{RD}$	Condition
0	0	1	0	Read DBB Data
0	1	1	0	Read STATUS
0	0	0	1	Write Data to DBB
0	1	0	1	Write Command to DBB
1	X	X	X	Disable 8278 Bus, High Impedance

Scan Counter

The scan counter provides the timing to scan the keyboard and display. The four MSB's (M_3-M_6) scan the display digits and provide column scan to the keyboard via a 4 to 16 decoder. The three LSB's (M_0-M_2) are used to multiplex the row return lines into the 8278.

Keyboard Debounce and Control

The 8278 system configuration is shown in Figure 3. The rows of the matrix are scanned and the outputs are multiplexed by the 8278. When a key closure is detected, the debounce logic waits about 12 msec to check if the key remains closed. If it does, the address of the key in the matrix is transferred into a FIFO buffer.

FIFO and FIFO Status

The 8278 contains an 8×8 FIFO character buffer. Each new entry is written into a successive FIFO location and each is then read out in the order of entry. A FIFO status register keeps track of the number of characters in the FIFO and whether it is full or empty. Too many reads or key entries will be recognized as an error. The status can be read by a $\overline{RD}$ with $\overline{CS}$ low and A_0 high. The status logic also provides a IRQ signal to the master processor whenever the FIFO is not empty.

Display Address Registers and Display RAM

The Display Address registers hold the address of the word currently being written or read by the CPU and the two 4-bit nibbles being displayed. The read/write addresses are programmed by CPU command. They also can be set to auto increment after each read or write. The display RAM can be directly read by the CPU after the correct mode and address is set. Data entry to the display can be set to either left or right entry.

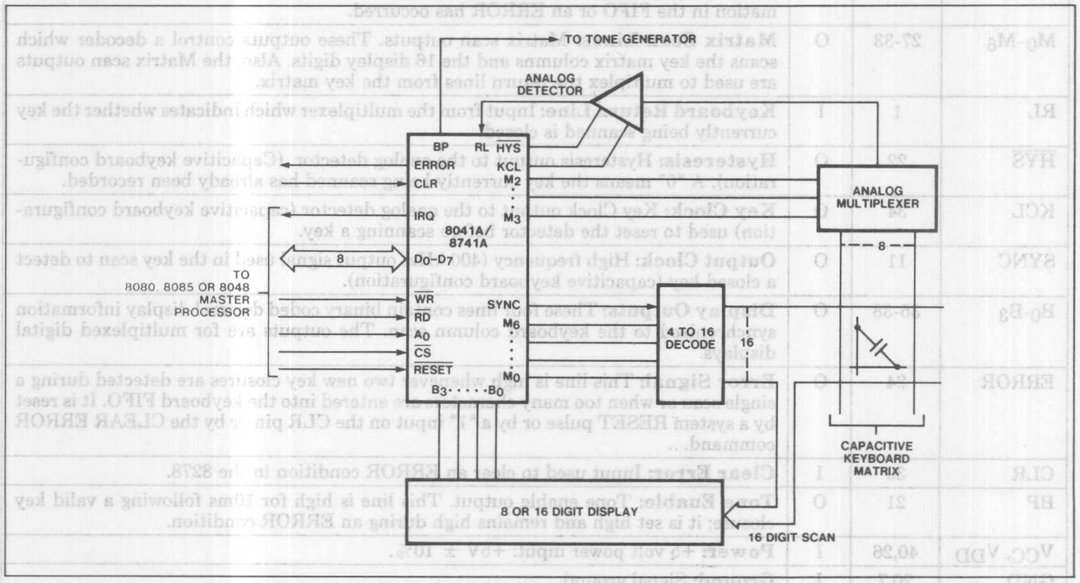


Figure 3. System Configuration for Capacitive-Coupled Keyboard

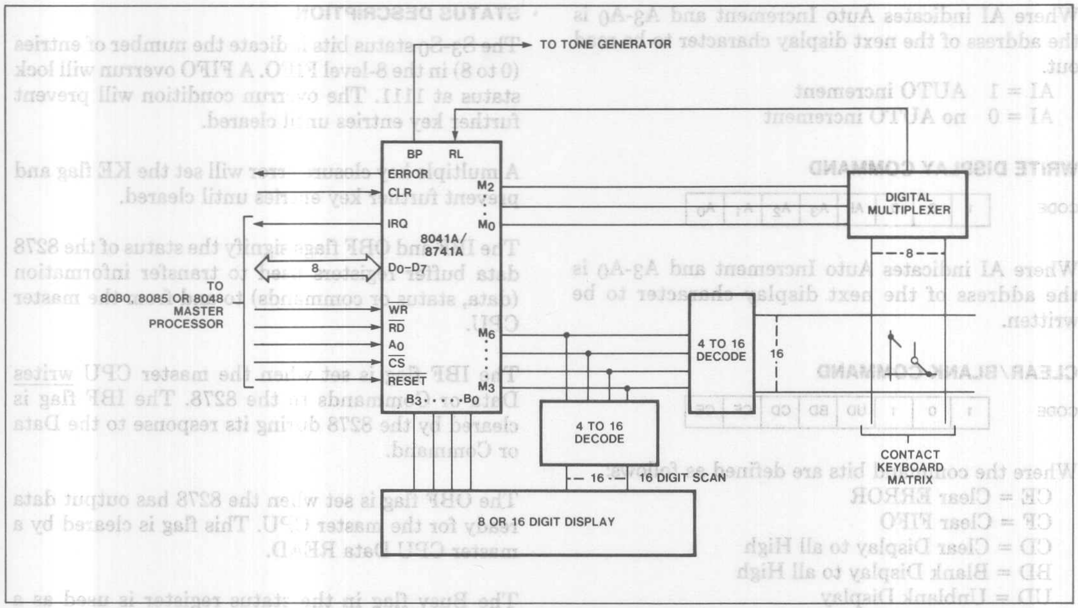
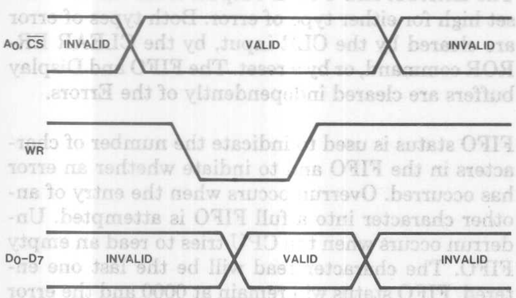


Figure 4. System Configuration for Contact Keyboard

COMMANDS

The 8278 operating mode is programmed by the master CPU using the A_0, WR and D_0-D_7 inputs as shown below:



The master CPU presents the proper command on the D_0-D_7 data lines with A_0 =1 and then sends a $\overline{WR}$ pulse. The command is latched by the 8278 on the rising edge of the $\overline{WR}$ and is decoded internally to set the proper operating mode. See the 8041A/8741A data sheet for timing details.

Command Summary

KEYBOARD/DISPLAY MODE SET

CODE	0	0	0	N	E	I	D	K

Where the mode set bits are defined as follows:

K—the keyboard mode select bit
- 0—normal key entry mode
- 1—special function mode: Entry on key closure and on key release

D—the display entry mode select bit
- 0—left display entry
- 1—right display entry

I—the interrupt request (IRQ) output enable bit.
- 0—enable IRQ output
- 1—disable IRQ output

E—the error mode select bit
- 0—error on multiple key depression
- 1—no error on multiple key depression

N—the number of display digits select
- 0—16 display digits
- 1—8 display digits

NOTE:
The default mode following a RESET input is all bits zero:

0	0	0	0	0	0	0	0

READ FIFO COMMAND

CODE	0	1	0	0	0	0	0	0

READ DISPLAY COMMAND

CODE	0	1	1	AI	A_3	A_2	A_1	A_0

Where AI indicates Auto Increment and A_3-A_0 is the address of the next display character to be read out.

AI = 1 AUTO increment
AI = 0 no AUTO increment

WRITE DISPLAY COMMAND

CODE								
	1	0	0	AI	A_3	A_2	A_1	A_0

Where AI indicates Auto Increment and A_3-A_0 is the address of the next display character to be written.

CLEAR/BLANK COMMAND

CODE								
	1	0	1	UD	BD	CD	CF	CE

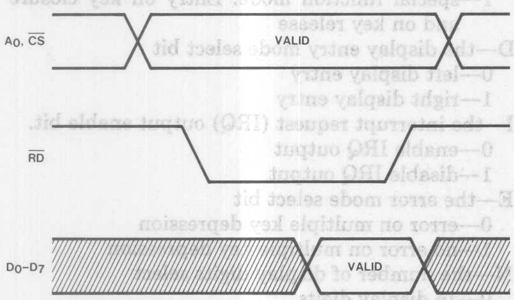
Where the command bits are defined as follows:

CE = Clear ERROR
CF = Clear FIFO
CD = Clear Display to all High
BD = Blank Display to all High
UD = Unblank Display

The display is cleared and blanked following a Reset.

Status Read

The status register in the 8278 can be read by the master CPU using the A_0, $\overline{RD}$, and D_0-D_7 inputs as shown below:



The 8278 places 8-bits of status information on the D_0-D_7 lines following (A_0, $\overline{CS}$, $\overline{RD}$) = 1, 0, 0 inputs from the master.

Status Format

S_3	S_2	S_1	S_0	B	KE	IBF	OBF
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

Where the status bits are defined as follows:

IBF = Input Buffer Full Flag
OBF = Output Buffer Full Flag
KE = Keyboard Error Flag (multiple depression)
B = BUSY Flag
S_3-S_0 = FIFO Status

STATUS DESCRIPTION

The S_3-S_0 status bits indicate the number of entries (0 to 8) in the 8-level FIFO. A FIFO overrun will lock status at 1111. The overrun condition will prevent further key entries until cleared.

A multiple key closure error will set the KE flag and prevent further key entries until cleared.

The IBF and OBF flags signify the status of the 8278 data buffer registers used to transfer information (data, status or commands) to and from the master CPU.

The IBF flag is set when the master CPU writes Data or Commands to the 8278. The IBF flag is cleared by the 8278 during its response to the Data or Command.

The OBF flag is set when the 8278 has output data ready for the master CPU. This flag is cleared by a master CPU Data READ.

The Busy flag in the status register is used as a LOCKOUT signal to the master processor during response to any command or data write from the master.

The master must test the Busy flag before each read (during a sequence) to be sure that the 8278 is ready with valid DATA.

The ERROR and TONE outputs from the 8278 are set high for either type of error. Both types of error are cleared by the CLR input, by the CLEAR ERROR command, or by a reset. The FIFO and Display buffers are cleared independently of the Errors.

FIFO status is used to indicate the number of characters in the FIFO and to indiate whether an error has occurred. Overrun occurs when the entry of another character into a full FIFO is attempted. Underrun occurs when the CPU tries to read an empty FIFO. The character read will be the last one entered. FIFO status will remain at 0000 and the error condition will not be set.

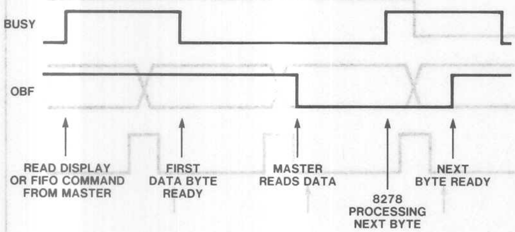
Data Read

The master CPU can read DATA from the 8278 FIFO or Display buffers by using the A_0, $\overline{RD}$, and D_0-D_7 inputs.

The master sends a $\overline{RD}$ pulse with A_0 = 0 and CS = 0 and the 8278 responds by outputting data on lines D_0-D_7. The data is strobed by the trailing edge of $\overline{RD}$.

DATA READ SEQUENCE

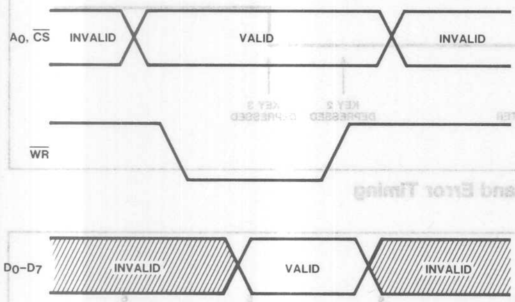
Before reading data, the master CPU must send a command to select FIFO or Display data. Following the command, the master must read STATUS and test the BUSY flag and the OBF flag to verify that the 8278 has responded to the previous command. A typical DATA READ sequence is as follows:



After the first read following a Read Display or Read FIFO command, successive reads may occur as soon as OBF rises.

Data Write

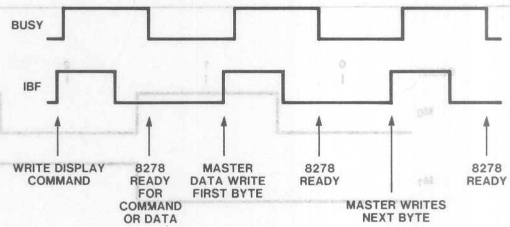
The master CPU can write DATA to the 8278 Display buffers by using the A_0, $\overline{WR}$ and D_0-D_7 inputs as follows:



The master CPU presents the Data on the D_0-D_7 lines with A_0=0 and then sends a $\overline{WR}$ pulse. The data is latched by the 8278 on the rising edge of $\overline{WR}$.

DATA WRITE SEQUENCE

Before writing data to the 8278, the master CPU must first send a command to select the desired display entry mode and to specify the address of the next data byte. Following the commands, the master must read STATUS and test the BUSY flag (B) and IBF flag to verify that the 8278 has responded. A typical sequence is shown below.



INTERFACE CONSIDERATIONS

Scanned Keyboard Mode

With N-key rollover each key depression is treated independently from all others. When a key is depressed the debounce logic waits for a full scan of 128 keys and then checks to see if the key is still down. If it is, the key is entered into the FIFO.

If two key closures occur during the same scan the ERROR output is set, the KE flag is set in the Status word, the TONE output is activated and IRQ is set, and no further inputs are accepted. This condition is cleared by a high signal on the CLEAR input or by a system $\overline{RESET}$ input or by the CLEAR ERROR command.

In the special function mode both the key closure and the key release cause an entry to the FIFO. The release is entered with the MSB=1.

Any key entry triggers the TONE output for 10ms.

The $\overline{HYS}$ and KCL outputs enable the analog multiplexer and detector to be synchronized for interface to capacitive coupled keyboards.

Data Format

In the scanned keyboard mode, the code entered into the FIFO corresponds to the position or address of the switch in the keyboard. The MSB is relevant only for special function keys in which code "0" signifies closure and "1" signifies release. The next four bits are the column count which indicates which column the key was found in. The last three bits are from the row counter.

BIT	7	6	5	4	3	2	1	0
	SF	M_6	M_5	M_4	M_3	M_2	M_1	M_0

SF: 1 FOR SPECIAL FUNCTION MODE AND KEY RELEASED
0 FOR KEY DEPRESSED

Display

Display data is entered into a 16×4 display register and may be entered from the left, from the right or

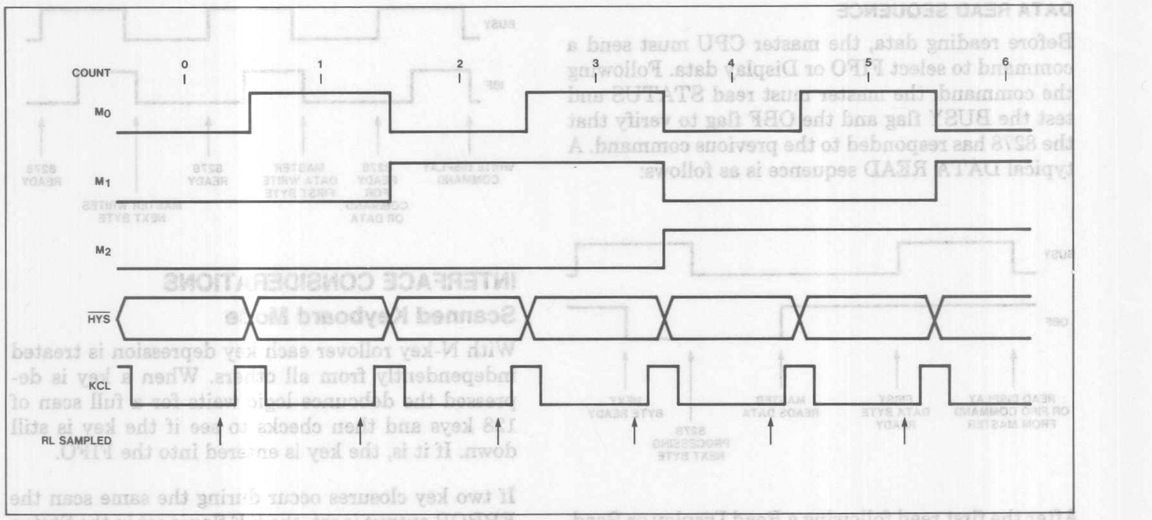


Figure 5. Keyboard Timing

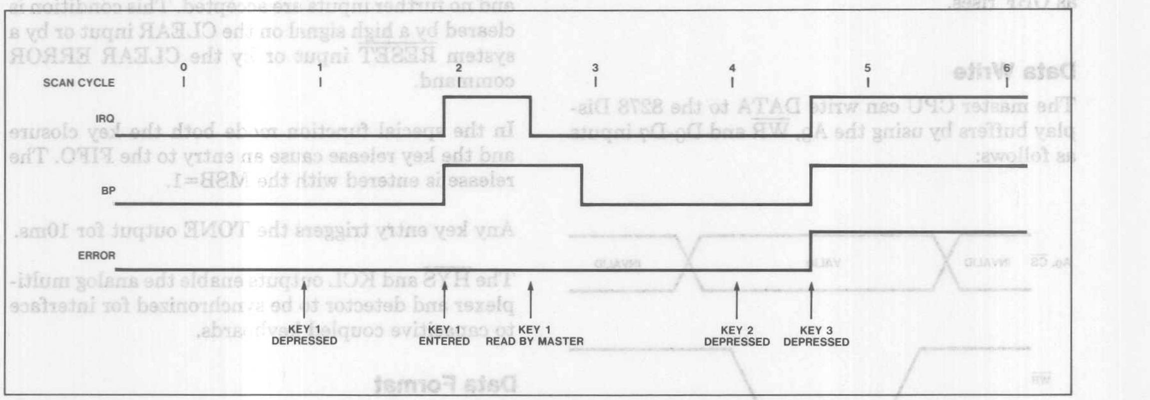


Figure 6. Key Entry and Error Timing

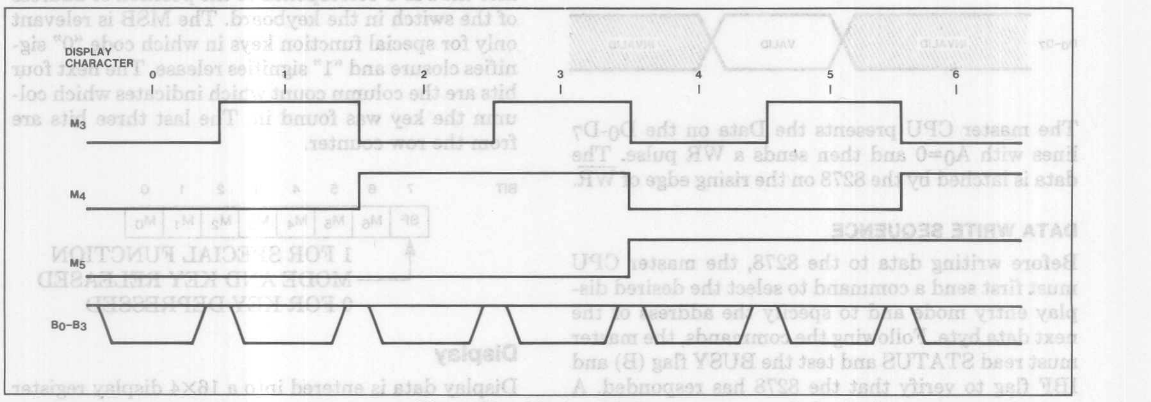


Figure 7. Display Timing

into specific locations in the display register. A new data character is put out on B_0-B_3 each time the M_6-M_3 lines change (i.e., once every 0.75ms with a 6 MHz crystal). Data is blanked during the time the column select lines change by raising the display outputs. Output data is positive true.

LEFT ENTRY

The left entry mode is the simplest display format in that each display position in the display corresponds to a byte (or nibble) in the Display RAM. ADDRESS 0 in the RAM is the left-most display character and ADDRESS 15 is the right-most display character. Entering characters from position zero causes the display to fill from the left. The 17th character is entered back in the left-most position and filling again proceeds from there.

RIGHT ENTRY

Right entry is the method used by most electronic calculators. The first entry is placed in the right-most display character. The next entry is also placed in the right-most character after the display is shifted left one character. The left-most character is shifted off the end and is lost.

	1	2		14	15	0.	DISPLAY RAM ADDRESS
1ST ENTRY						1	
	2	3		15	0	1	
2ND ENTRY					1	2	
	3	4		0	1	2	
3RD ENTRY				1	2	3	
	0	1		13	14	15	
16TH ENTRY	1	2		14	15	16	
	1	2		14	15	0	
17TH ENTRY	2	3		15	16	17	
	2	3		15	0	1	
18TH ENTRY	3	4		16	17	18	

Note that now the display position and register address do not correspond. Consequently, entering a character to an arbitrary position in the Auto Increment mode may have unexpected results. Entry starting at Display RAM ADDRESS 0 with sequential entry is recommended. A Clear Display command should be given before display data is entered if the number of data characters is not equal to 16 (or 8) in this mode.

AUTO INCREMENT

In the Left Entry mode, Auto Incrementing causes the address where the CPU will next write to be incremented by one and the character appears in the next location. With non-Auto Incrementing the entry is both to the same RAM address and display position. Entry to an arbitrary address in the Left Entry—Auto Increment mode has no undesirable side effects and the result is predictable:

	0	1	2	3	4	5	6	7	DISPLAY RAM ADDRESS
1ST ENTRY	1								
	0	1	2	3	4	5	6	7	
2ND ENTRY	1	2							
	0	1	2	3	4	5	6	7	
COMMAND 10010101	1	2							

ENTER NEXT AT LOCATION 5 AUTO INCREMENT

	0	1	2	3	4	5	6	7
3RD ENTRY	1	2				3		
	0	1	2	3	4	5	6	7
4TH ENTRY	1	2				3	4	

In the Right Entry mode, Auto Incrementing and non-Incrementing have the same effect as in the Left Entry except that the address sequence is interrupted.

	1	2	3	4	5	6	7	0	DISPLAY RAM ADDRESS
1ST ENTRY								1	
	2	3	4	5	6	7	0	1	
2ND ENTRY							1	2	
	2	3	4	5	6	7	0	1	
COMMAND 10010101							1	2	

ENTER NEXT AT LOCATION 5 AUTO INCREMENT

	3	4	5	6	7	0	1	2
3RD ENTRY			3			1	2	
	4	5	6	7	0	1	2	3
4TH ENTRY		3	4		1	2		

Starting at an arbitrary location operates as shown below.

COMMAND 10010101									DISPLAY RAM ADDRESS
	0	1	2	3	4	5	6	7	

ENTER NEXT AT LOCATION 5 AUTO INCREMENT

	1	2	3	4	5	6	7	0
1ST ENTRY					1			
	2	3	4	5	6	7	0	1
2ND ENTRY				1	2			
8TH ENTRY	4	5	6	7	8	1	2	3
9TH ENTRY	5	6	7	8	9	2	3	4

Entry appears to be from the initial entry point.

Using the 8295 Dot Matrix Printer Controller

Contents

INTRODUCTION

Many microprocessor systems require the real-time control of a peripheral device such as a printer, keyboard, or alpha-numeric display, etc. These medium speed but still real-time tasks can be rather mundane, time-consuming, and require a fair amount of system software overhead. Of course, any time spent by the main processor in servicing these I/O devices is unavailable for other, possibly more important, tasks. This processor burden can largely be removed by isolating the real-time portion of the task to a dedicated peripheral-control processer.

Until recently, this approach was usually not cost effective due to the large number of components required by the dedicated processor: CPU, RAM, ROM, I/O, etc. To help make the approach more cost effective, Intel borrowed the I/O processing concepts found in many mainframe and minicomputers; put all the hardware in one package; and introduced a family of Universal Peripheral Interface controllers—the UPI-41A™ family. The basic family consists of the 8041A and the 8741A. These two devices are essentially single-chip microcomputers with a standard microprocessor bus interface. They have on-chip RAM, ROM (8041A) or EPROM (8741A), CPU, timer/counter, and I/O. Using one of the UPI family, the designer simply codes his custom or proprietary peripheral control algorithm into the UPI device itself rather than the main system software. The UPI device then takes over the peripheral control task while the host processor simply issues commands and transfers data. More information on the UPI family is available in the documents referenced opposite the table of contents.

Illustrating the UPI concept as both design examples and actual products, a number of pre-programmed 8041As are available. These devices are the 8278 Keyboard/Display Controller, the 8294 Data Encryption Unit, the 8292 GPIB Controller, and the 8295 Dot Matrix Printer Controller. Data sheets for these devices are found in the Peripheral Design Handbook and their source listings (except for the 8294) are available in Insite, Intel's User's library. This application note deals with the 8295.

THE 8295

The 8295 Dot Matrix Printer Controller is a device specifically designed to interface microprocessors to the LRC 7040 Series of dot matrix impact printers. It offers complete solenoid and motor drive timing and contains an on-chip 7×7 character generator accommodating 64 ASCII characters. An on-chip FIFO buffers up to 40 ASCII characters before printing. Character density, width, and print intensity are all programmable. Three programmable tabulations and two general purpose outputs are also provided. Four data transfer methods are possible: polling, interrupt-driven, and Direct Memory Access (DMA) are available when in parallel data transfer mode and asynchronous serial is available in serial mode. The data transfer mode is hardware selectable.

Let's first look at the LRC printer itself and its interface to the 8295.

THE LRC 7040 PRINTER

The LRC Model 7040 printer is manufactured by LRC, Inc. of Riverton, Wyoming. Capable of printing 40 columns of characters at a speed of 1.25 lines/sec, the 7040 is mechanically simple and is ideal for point-of-sale or data logging terminals.

It is an impact printer whose print head consists of seven solenoids which each drives a stiff wire to impact the paper through an inked ribbon. While the wires are arranged in a circular fashion at the solenoid end, they form a vertical column at the ribbon impact point. Characters are formed by firing the solenoids to form a 5×7 or 7×7 matrix of "dots" (impacts of the wires). Figure 1 shows how the character A is formed using a 7×7 matrix. The columns are labeled C1 thru C7 and the rows R1 thru R7. The print head moves left to right across the paper so at time T1, the head is over column C1. If the correct solenoids are activated at each time Tx for each column Cx, the character is formed.

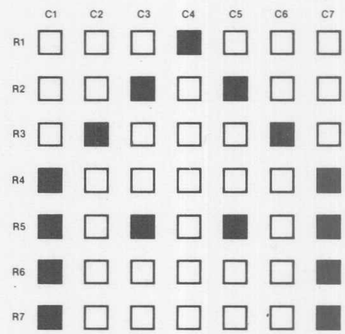


Figure 1. Character A in 7×7 Format

The print head is moved across the paper by the main motor drive. The main motor drive consists of a 24-pole synchronous motor which drives a rotating plastic drum. The drum has a spiral groove molded into it and a pin on the print head rests in the groove so that the print head traverses the paper as the drum rotates. Characters are printed by firing the solenoids during the left-to-right traverse. At the end of the print area, the spiral groove reverses the direction of the print head returning it to its home position.

A HOME microswitch riding on a cam attached to the plastic drum provides the only feedback as to the print head position. When the print head is in its home resting position the HOME switch is inactive. To start a print cycle, the main motor drive is activated which starts the print head motion. As the print head reaches the beginning of the print area, the cam activates the HOME switch as a signal to the printer controller to commence firing the solenoids. The controller then activates the solenoids as appropriate for each character in the line. The print area is defined as the 310ms immediately after HOME goes active. Solenoid timing is the responsibility of the controller; the printer mechanism supplies no character-position information.

After the line is printed and the print head has traversed right to left, the HOME switch is deactivated. This transition signals the controller to turn off the main motor drive since the home position has been reached. A new print cycle may start immediately if data is ready.

Paper feed is accomplished with a second synchronous motor and a PFEED (Paper Feed) microswitch. In the quiescent state, the PFEED switch is inactive. Activating the paper feed motor drive starts the line feed cycle. The switch becomes active at some point during the cycle (typically about 48ms later) and is deactivated when the cycle is complete. The controller uses the active-to-inactive transition to remove the paper feed motor drive. The paper feed operation is independent of the print cycle so the two could occur simultaneously. Figure 2 shows the timing required by the printer for a print cycle followed by a line feed.

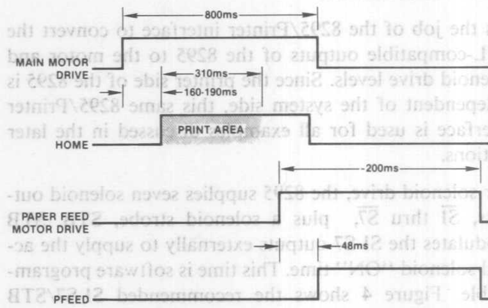


Figure 2. LRC 7040 Motor Drive Timing

Solenoid timing determines the location of any given "dot" and its intensity. The LRC 7040 printer specification states a 400μs maximum solenoid "ON" time and a 1.3ms typical period. Since the print area is 310ms "long," this timing allows a total of 240 dots (310ms/1.3ms per dot) in one row or 40 characters on a 5×7 matrix with a one dot space between characters. While 5×7 characters have acceptable readability, their distinctness and format can be improved with a 7×7 matrix, however, 40 7×7 characters translate to 320 dots per row or a 0.97ms solenoid period. This violates the solenoid duty cycle spec if the solenoids are fired for every column. The best way to get around this dilemma and still retain the improved readability of the 7×7 format is to simply fire the solenoid every other column. The 8295 uses this technique and the "every-other" column spacing is reflected in Figure 1. The 8295 character set is included in Figure 3.

CHARACTER SET

Hex Code	Print Char.	Hex Code	Print Char.	Hex Code	Print Char.	Hex Code	Print Char.
20	space	30	0	40	@	50	P
21	!	31	1	41	A	51	Q
22	"	32	2	42	B	52	R
23	#	33	3	43	C	53	S
24	$	34	4	44	D	54	T
25	%	35	5	45	E	55	U
26	&	36	6	46	F	56	V
27	'	37	7	47	G	57	W
28	(	38	8	48	H	58	X
29	)	39	9	49	I	59	Y
2A	*	3A	:	4A	J	5A	Z
2B	+	3B	;	4B	K	5B	[
2C	,	3C	<	4C	L	5C	\
2D	—	3D	=	4D	M	5D	]
2E	.	3E	>	4E	N	5E	↑
2F	/	4F	?	4F	O	5F	—

Figure 3. 8295 Character Set

AFN-00875A

8295/Printer Interface

It's the job of the 8295/Printer interface to convert the TTL-compatible outputs of the 8295 to the motor and solenoid drive levels. Since the printer side of the 8295 is independent of the system side, this same 8295/Printer interface is used for all examples discussed in the later sections.

For solenoid drive, the 8295 supplies seven solenoid outputs, $\overline{S1}$ thru $\overline{S7}$, plus a solenoid strobe, STB. STB modulates the S1-S7 outputs externally to supply the actual solenoid "ON" time. This time is software programmable. Figure 4 shows the recommended S1-S7/STB gating.

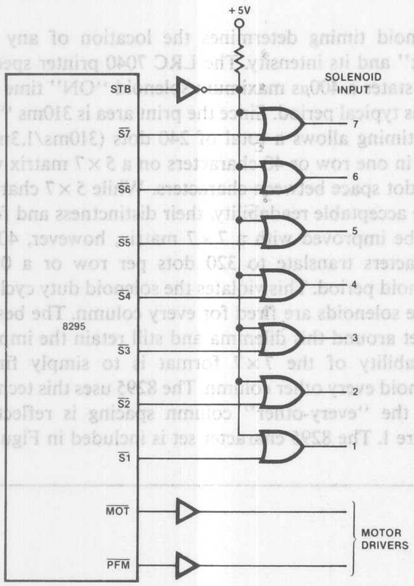


Figure 4. Solenoid and Motor Gating

The solenoids must be driven from a 40 ±10% volt source. The peak current is approximately 3.6A, the average current is approximately 0.5A. A circuit providing the required drive is shown in Figure 5. The output stage, consisting of the 2N6045 Darlington transistor, the 1N4002 catching diode, and the 100-ohm damping resistor, is the one suggested by the manufacturer. The input stage is a discrete implementation of a DTL gate. Note that the base-emitter junction of the 2N6045 protects the 2N2222A transistor from overvoltage on its collector. This circuit has several features which are important to the printer interface:

1. All solenoid power (including the power used to drive the base of the power transistor) is derived from the 40-volt supply.
2. Disconnecting the drivers from the 8295 or the loss of the 5-volt supply to the 8295 results in the solenoids turning off.

The first feature of the drivers minimizes the impact of the printer and its interface on the 5-volt supply. The second feature prevents the activation of the solenoids erroneously during power on/off cycles or during system checkout. This an important point since the solenoids will be damaged if left activated continuously. The fuses is series with the solenoids help protect them from mishap.

The two motors can each be driven as shown in Figure 6. The Monsanto MCS-6200 is an optically-coupled TRIAC which is ideal for driving the small synchronous motors in the printer. Coupled with a buffer this part provides a simple means of controlling the motors without sacrificing the isolation required for safe and reliable operation.

These driver circuits were borrowed from the Intel application note AP-27 "Printer Control With the UPI-41." (The 8295 development was inspired by the success of the AP-27 design.) Other solenoid and motor driver circuits are described in the LRC Interface Guide available from the manufacturer.

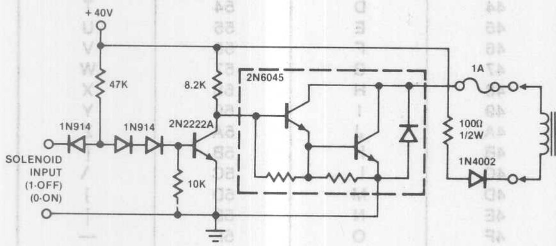


Figure 5. Solenoid Driver

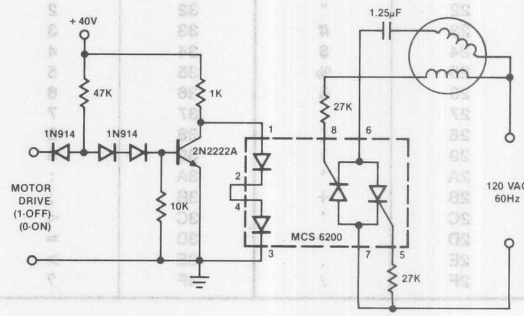


Figure 6. Motor Driver

COMMAND SET

Hex Code	Description
00	Clear GP1. This command brings the GP1 pin to a logic low state. After power on it is automatically set high.
01	Clear GP2. Same as the above but for GP2.
02	Set GP1. Sets GP1 pin to a logic high state, inverse of command 00.
03	Set GP2. Same as above but for GP2. Inverse command 01.
04	Software Reset. This is a pacify command. This command is not effective immediately after commands requiring a parameter, as the Reset command will be interpreted as a parameter.
05	Print 10 characters/in. density.
06	Print 12 characters/in. density.
07	Print double width characters. This command prints characters at twice the normal width, that is, at either 17 or 20 characters per line.
08*	Enable DMA mode; must be followed by two bytes specifying the number of data characters to be fetched. Least significant byte accepted first.
09	Tab character.
0A	Line feed.
0B*	Multiple Line Feed; must be followed by a byte specifying the number of line feeds.
0C	Top of Form. Enables the line feed output until the Top of Form input is activated.
0D	Carriage Return. Signifies end of a line and enables the printer to start printing.
0E*	Set Tab #1, followed by tab position byte.
0F*	Set Tab #2, followed by tab position byte. Should be greater than Tab #1.
10*	Set Tab #3, followed by tab position byte. Should be greater than Tab #1.
11	Print Head Home on Right. On some printers the print head home position is on the right. This command would enable normal left to right printing with such printers.
12*	Set Strobe Width; must be followed by strobe width selection byte. This command adjusts the duration of the strobe activation.

D7-D3	D2	D1	D0	Solenoid on (µs)
0	0	0	0	200
0	0	0	1	240
0	0	1	0	280
0	0	1	1	320
0	1	0	0	360
0	1	0	1	400
0	1	1	0	440
0	1	1	1	480

*parameter(s) required

Figure 7. 8295 Command Set

8295 Command Software

The software control of the 8295 is very straightforward. The host processor simply issues ASCII characters to the 8295. The printable characters, 20H thru 5FH, are stored in the on-chip FIFO for printing while the non-printable codes, 00H thru 12H, serve as 8295 commands. (Codes 13H thru 1FH are treated as no-ops.) The 8295 command set is shown in Figure 7. Note that some of the commands require an extra byte or two of information (parameters). These additional parameters must follow the command otherwise data and parameters might be confused. Commands and data may be mixed at any time although while the data is stored in the FIFO, commands take effect immediately. Commands do not "pass-thru" the FIFO.

All printable characters are entered into the FIFO. The FIFO is printed when either a Carriage Return command is received or the FIFO becomes full. In either case, the FIFO is printed, however there is no automatic line feed unless the printer happens to be so equipped mechanically. Thus, a Line Feed command should be issued after each Carriage Return or after the last character to fill the FIFO. The FIFO is printed as soon as the character that filled it is accepted. If the character immediately following this filling character is a Carriage Return, the 8295 ignores it to prevent a useless print cycle.

Some commands clear the FIFO. The Carriage Return command effectively clears the FIFO since it causes the FIFO contents to be printed. The character density and width commands also clear the FIFO however they do not print its contents; the FIFO size is adjusted by these commands. Obviously, a 10 chr/in density with double width printing would not allow 40 characters per line. The 8295 recognizes this fact and modifies internally the FIFO size limits. The FIFO size is modified according to the table below. For example, if the density is 10 char/in, single width printing, the 8295 accepts only 33 printable

characters before starting a print cycle. Since these commands take effect as soon as they are accepted, this prevents mixing different character densities or widths on a given line. Any such commands must precede the data for a line.

DENSITY	WIDTH	BUFFER SIZE
12	SINGLE	40
12	DOUBLE	20
10	SINGLE	33
10	DOUBLE	17

The Software Reset command clears the FIFO, resets the density to 12 chr/in and selects single width printing. It does not effect the solenoid strobe width, the tab positions, or the general purpose outputs. This command should be issued only when the 8295 is expecting a command or data. Issuing it when the 8295 is expecting a parameter causes it to be interpreted as the parameter and not the intended software reset.

A hardware reset causes the 8295 to default into the following states:

1. Clears the FIFO
2. GP1 and GP2 set high
3. 12 chr/in density
4. single width prining
5. 320μs strobe width
6. tab positions indeterminate.

Parallel Interfaces

The 8295 has the option of using serial or parallel communication with the main processor. The choice must be made early in the design cycle since it is a hardware, not a software, selection. Let's look at the parallel options first.

In parallel mode, the 8295 has the traditional microprocessor bus interface: data, control, etc. The parallel mode is selected by not grounding the $IRQ/\overline{SER}$ pin. To the main processor, the 8295 in parallel mode appears as two registers: the Input Data register and the Output Status register. The main processor writes commands and data into the Input Data register while it reads the 8295 status from the Output Status register.

The Output Status register format is shown in Figure 8. The Input Buffer Full bit (IBF) indicates whether the 8295 has accepted the previous command or data byte. IBF is automatically set when the host processor writes to the 8295 and it is reset when the 8295 accepts the data or command. If IBF = 1, no writes to the Input Data register are allowed. Only when IBF = 0 may a Input Data register write be done. The DMA Enable bit (DE) is set whenever the 8295 is performing DMA data transfers. When the specified number of transfers has been made, the DE bit is cleared. Since DMA cycles are usually transparent to the main processor, the DE bit tells the processor when the DMA block transfer is complete.

The processor does not always have to read the Output Status register, checking IBF, before loading the Input Data register. An interrupt output (IRQ) pin is available to interrupt the processor whenever the 8295 is ready to receive new data or commands. The fact that IRQ is set implies that IBF = 0, so it's not necessary for the processor to read the 8295 status when interrupted; it can just write the next byte.

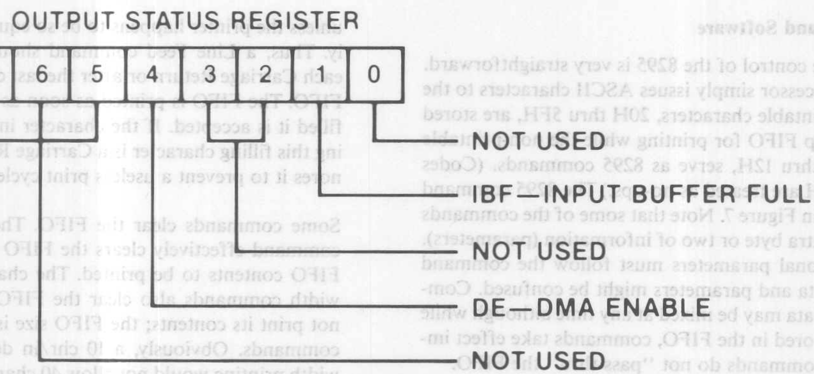


Figure 8. Output Status Register Format

Figure 9 shows the system schematic for using the 8295 in polled-parallel mode in an 8085A system; ie the IRQ line is not used. The 8085A/8295 interface is standard as for any Intel peripheral. $\overline{CS}$ is decoded from the high-order address lines. $\overline{RD}$ and $\overline{WR}$ are the 8085A read and write control lines. $\overline{RESET}$ is the system reset.

Example 8085A polling software is shown in Figure 10. This routine simply outputs the print buffer starting at the location pointed to in PRTSRT. The system software builds the buffer, terminates it with a 0FFH character, and loads PRTSRT before calling PRINT.

PRINT is not very efficient with respect to processing time. Since the 8295 does not accept data while in a print or line feed cycle, if the buffer contained more printable characters than the FIFO size, the processor would sit in the PRT2 loop during the 800ms print and 200ms line feed cycles. That is obviously not too efficient. The obvious way around this problem is to restrict the buffer size to less than that of the FIFO however this could complicate the system software since more buffer building is required. A better approach is to use interrupts.

By connecting the 8295's IRQ output to one of the 8085A RST interrupt inputs (dotted line in Figure 9), the processor is interrupted only when the 8295 is able to take another character. Figure 11 shows such interrupt-driven software assuming the RST 6.5 interrupt input is used for IRQ.

To further enhance the bus efficiency and processor overhead at the expense of slightly more complex hardware, use the 8295 DMA interface. This DMA interface is compatible with the 8257 DMA Controller. With such an interface all that's necessary is for the processor to load the DMA Controller with the print buffer starting address and write the Enable DMA command and length parameters into the 8295. The 8295 does the rest by requesting data directly from memory thru the DMA Controller. It keeps track of the number of characters to request. As long as there are characters remaining to be transferred, the DE bit in the Output Status register is set. After the last byte is transferred into the 8295, the DE bit is reset and the IRQ is made active. Either event is used to tell the processor that DMA is complete and the 8295 is ready for the next block. It is not necessary to restrict the DMA block size to 40 characters, the Enable DMA command parameters allow for up to 65k byte block sizes. The block size given the 8295 must reflect both data plus commands and parameters.

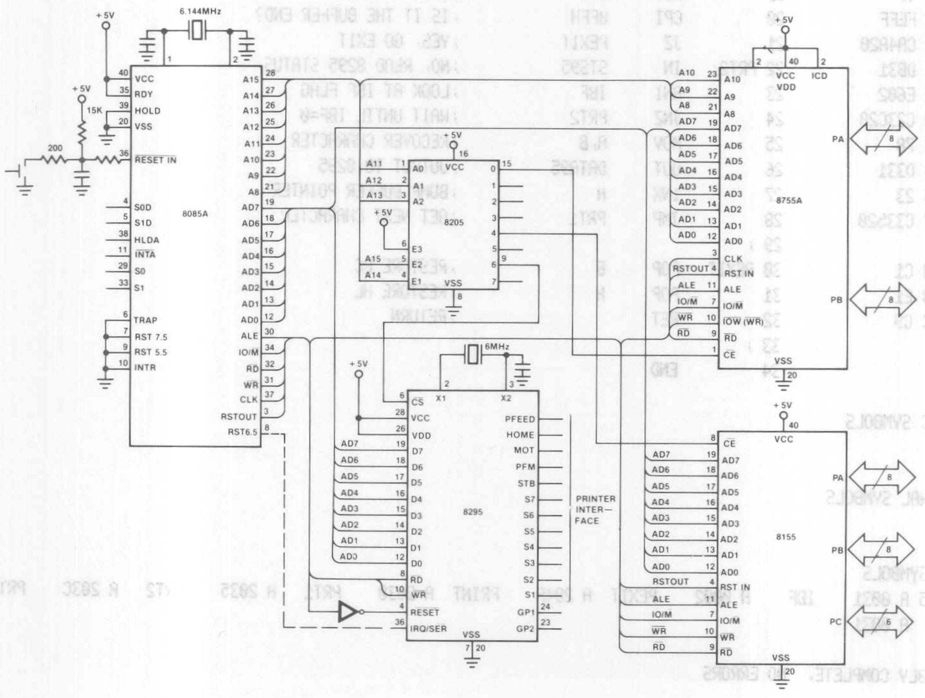


Figure 9. 8295 Parallel Interface

```
ASM80 :F1:95F10.SRC TITLE('8295 AP NOTE FIGURE 10')

ISIS-II 8080/8085 MACRO ASSEMBLER, X108                 MODULE
8295 AP NOTE FIGURE 10

 LOC  OBJ       SEQ        SOURCE STATEMENT

                  1 $MOD85
                  2 ;
                  3 ;SYSTEM EQUATES
 20D0             4 PRTSRT  EQU     20D0H               ;POINTER STORAGE
 0002             5 IBF     EQU     02H                 ;IBF FLAG MASK
 0031             6 STS95   EQU     31H                 ;8295 STATUS REGISTER PORT
 0031             7 DATA95  EQU     31H                 ;8295 DATA REGISTER PORT
                  8 ;
 2030             9         ORG     2030H
                 10 ;
                 11 ;PRINT BUFFER OUTPUT SUBROUTINE - THIS ROUTINE PRINTS THE BUFFER
                 12 ;STARTING AT THE POINTER STORED AT PRTSRT.  THE ROUTINE RETURNS WHEN
                 13 ;A 0FFH IS FETCHED FROM THE BUFFER.
                 14 ;
 2030 E5         15 PRINT:  PUSH    H                   ;SAVE HL
 2031 C5         16         PUSH    B                   ;SAVE BC
 2032 2AD020     17         LHLD    PRTSRT              ;GET BUFFER POINTER
 2035 7E         18 PRT1:   MOV     A,M                 ;GET CHARACTER FROM BUFFER
 2036 47         19         MOV     B,A                 ;SAVE IT IN B
 2037 FEFF       20         CPI     0FFH                ;IS IT THE BUFFER END?
 2039 CA4A20     21         JZ      PEXIT               ;YES, GO EXIT
 203C DB31       22 PRT2:   IN      STS95               ;NO, READ 8295 STATUS
 203E E602       23         ANI     IBF                 ;LOOK AT IBF FLAG
 2040 C23C20     24         JNZ     PRT2                ;WAIT UNTIL IBF=0
 2043 78         25         MOV     A,B                 ;RECOVER CHARACTER
 2044 D331       26         OUT     DATA95              ;OUTPUT TO 8295
 2046 23         27         INX     H                   ;BUMP BUFFER POINTER
 2047 C33520     28         JMP     PRT1                ;GET NEXT CHARACTER
                 29 ;
 204A C1         30 PEXIT:  POP     B                   ;RESTORE BC
 204B E1         31         POP     H                   ;RESTORE HL
 204C C9         32         RET                         ;RETURN
                 33 ;
                 34         END

PUBLIC SYMBOLS


EXTERNAL SYMBOLS


USER SYMBOLS
DATA95 A 0031   IBF    A 0002   PEXIT  A 204A   PRINT  A 2030   PRT1   A 2035   PRT2   A 203C   PRTSRT A 20D0
STS95  A 0031

ASSEMBLY COMPLETE,  NO ERRORS
```

Figure 10. 8085A/8295 Polling Subroutine

```
ASM80 :F1:95F11.SRC TITLE('8295 AP NOTE FIGURE 11')

ISIS-II 8080/8085 MACRO ASSEMBLER, X108        MODULE
8295 AP NOTE FIGURE 11

  LOC  OBJ         SEQ        SOURCE STATEMENT

                     1 $MOD85
                     2 ;
                     3 ;SYSTEM EQUATES
  20D0               4 PRTSRT  EQU    20D0H       ;POINTER STORAGE
  0002               5 IBF     EQU    02H         ;IBF FLAG MASK
  0031               6 ST595   EQU    31H         ;8295 STATUS REGISTER PORT
  0031               7 DATA95  EQU    31H         ;8295 DATA REGISTER PORT
                     8 ;
                     9 ;
                    10 ;RST6.5 INTERRUPT VECTOR LOCATION - JUMP TO PRINTER SUBROUTINE
                    11 ;
  0034              12         ORG    34H
                    13 ;
  0034 C33020       14 RST65:  JMP    PRINT       ;GO TO PRINT ROUTINE
                    15 ;
                    16 ;
  2030              17         ORG    2030H
                    18 ;
                    19 ;PRINTER OUTPUT SUBROUTINE FOR INTERRUPT-DRIVEN SYSTEM - OUTPUTS
                    20 ;CHR POINTED AT BY PRTSRT.  IF CHR IS 0FFH, THE BUFFER IS COMPLETE
                    21 ;AND THE RST6.5 INTERRUPT IS MASKED.  THE MAIN PROGRAM MUST UNMASK
                    22 ;RST6.5 AFTER IT BUILDS A NEW BUFFER.  PRINT BUFFER STATUS IS REFLECTED
                    23 ;TO THE MAIN PROGRAM BY THE RST6.5 MASK BIT IN RIM INSTRUCTION.
                    24 ;
  2030 E5           25 PRINT:  PUSH   H           ;SAVE HL
  2031 F5           26         PUSH   PSW         ;SAVE PSW
  2032 2AD020       27         LHLD   PRTSRT      ;GET BUFFER POINTER
  2035 7E           28         MOV    A,M         ;GET NEXT CHR
  2036 FEFF         29         CPI    0FFH        ;TEST IF BUFFER COMPLETE
  2038 CA4520       30         JZ     EXIT        ;YES, GO EXIT WITH RST MASKED
  203B D331         31         OUT    DATA95      ;NO, OUTPUT CHR TO 8295
  203D 23           32         INX    H           ;BUMP POINTER
  203E 22D020       33         SHLD   PRTSRT      ;RESTORE POINTER
  2041 F1           34 PRT1:   POP    PSW         ;RESTORE PSW
  2042 E1           35         POP    H           ;RESTORE HL
  2043 FB           36         EI                 ;RE-ENABLE INTERRUPTS
  2044 C9           37         RET                ;RETURN
                    38 ;
  2045 3E0A         39 EXIT:   MVI    A,0AH       ;MASK RST6.5
  2047 30           40         SIM                ;SET INTERRUPT MASK
  2048 C34120       41         JMP    PRT1        ;GO EXIT WITH MASK IN PLACE
                    42 ;
                    43         END

PUBLIC SYMBOLS

EXTERNAL SYMBOLS

USER SYMBOLS
DATA95 A 0031   EXIT  A 2045   IBF   A 0002   PRINT  A 2030   PRT1  A 2041   PRTSRT A 20D0   RST65  A 0034
```

Figure 11. 8085A/8295 Interrupt-Driven Software

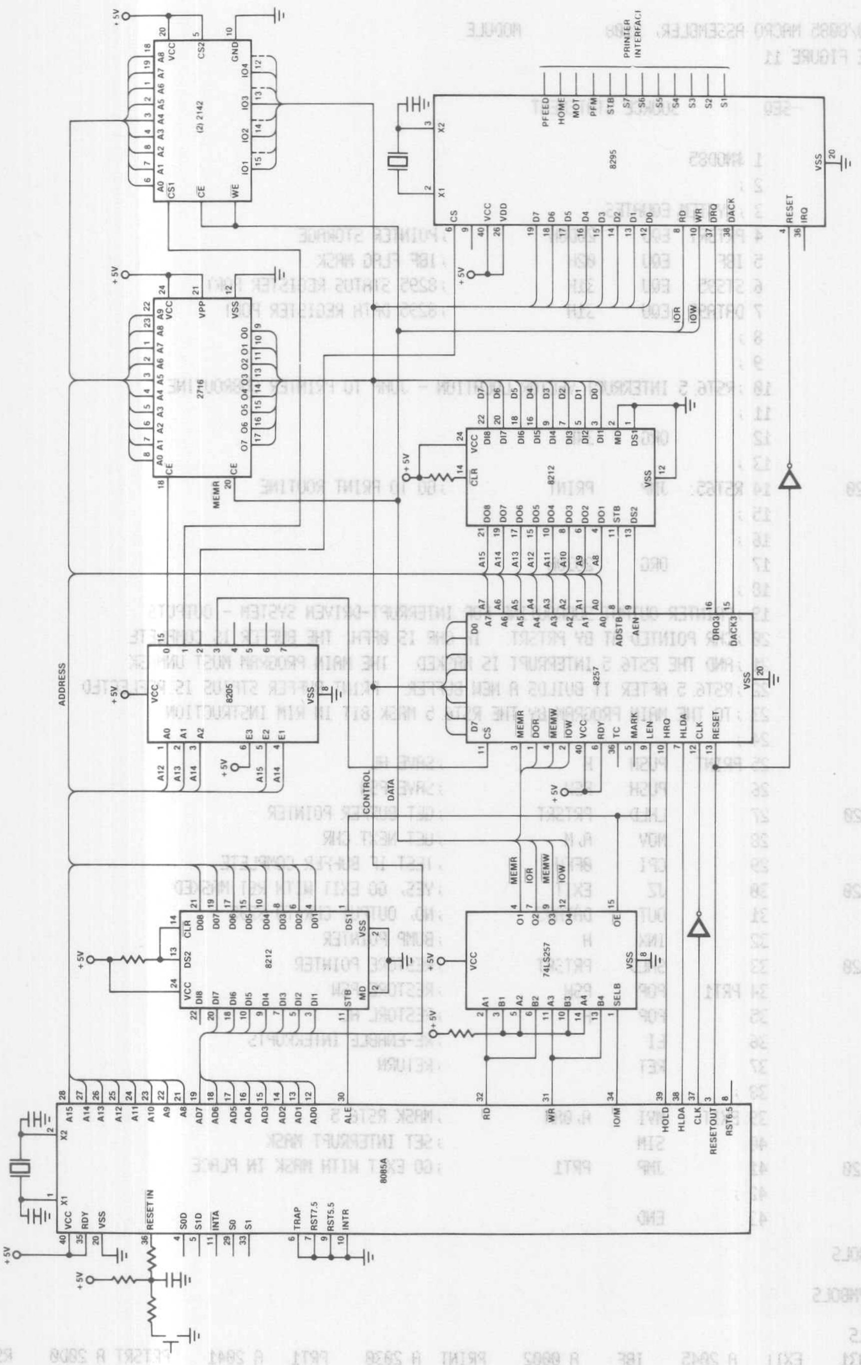


Figure 12. 8295/DMA Interface

```
ASM80 :F1:95F13.SRC TITLE('8295 AP NOTE FIGURE 13')

ISIS-II 8080/8085 MACRO ASSEMBLER, X108                MODULE    PAGE    1
8295 AP NOTE FIGURE 13

 LOC  OBJ          SEQ        SOURCE STATEMENT

                     1 $MOD85
                     2 ;
                     3 ;SYSTEM EQUATES:
 0038                4 MODE57   EQU    38H             ;8257 CONTROL PORT
 0036                5 CH3ADR   EQU    36H             ;8257 CH3 ADR PORT
 0037                6 CH3TC    EQU    37H             ;8257 CH3 TC PORT
 0002                7 IBF      EQU    02H             ;IBF MASK
 0020                8 STS95    EQU    20H             ;8295 STATUS PORT
 0020                9 DATA95   EQU    20H             ;8295 DATA PORT
                    10 ;
 2030               11          ORG    2030H
                    12 ;
                    13 ;DMA-DRIVEN PRINT ROUTINE - THE MAIN PROGRAM CALLS THIS SUBROUTINE
                    14 ;AFTER BUILDING A PRINT BUFFER AND TESTING THE 8295 DE BIT FOR
                    15 ;COMPLETION OF THE LAST DMA BLOCK TRANSFER.  THE STARTING ADDRESS
                    16 ;OF THE PRINT BUFFER IS PASSED IN THE DE REGISTER PAIR, THE COUNT IN BC.
                    17 ;
 2030 3E07          18 PRINT:   MVI    A,07H           ;DISABLE DMA CH3
 2032 D338          19          OUT    MODE57          ;8257 CONTROL PORT
 2034 7B            20          MOV    A,E             ;GET ADR LSB
 2035 D336          21          OUT    CH3ADR          ;8257 CH3 ADR PORT
 2037 7A            22          MOV    A,D             ;GET ADR MSB
 2038 D336          23          OUT    CH3ADR          ;8257 CH3 ADR PORT
 203A 3EFF          24          MVI    A,0FFH          ;MAKE CH3 TC FFFFH
 203C D337          25          OUT    CH3TC           ;8257 CH3 TC PORT
 203E 3EBF          26          MVI    A,0BFH          ;DMA DIRECTION IS MEMORY READ
 2040 D337          27          OUT    CH3TC           ;8275 CH3 TC PORT
 2042 1608          28          MVI    D,08H           ;ENABLE DMA COMMAND TO 8295
 2044 CD5420        29          CALL   OUT95           ;OUTPUT TO 8295
 2047 51            30          MOV    D,C             ;GET LSB OF COUNT
 2048 CD5420        31          CALL   OUT95           ;OUTPUT TO 8295
 204B 50            32          MOV    D,B             ;GET MSB OF COUNT
 204C CD5420        33          CALL   OUT95           ;OUTPUT TO 8295
 204F 3E0F          34          MVI    A,0FH           ;ENABLE CH3 DMA
 2051 D338          35          OUT    MODE57          ;8257 CONTROL PORT
 2053 C9            36          RET                    ;RETURN
                    37 ;
 2054 DB20          38 OUT95    IN     STS95           ;READ 8295 STATUS
 2056 E602          39          ANI    IBF             ;LOOK AT IBF FLAG
 2058 C25420        40          JNZ    OUT95           ;WAIT UNTIL IBF=0
 205B 7A            41          MOV    A,D             ;GET DATA
 205C D320          42          OUT    DATA95          ;OUTPUT TO 8295 PORT
 205E C9            43          RET                    ;RETURN
                    44 ;
                    45          END

PUBLIC SYMBOLS
EXTERNAL SYMBOLS
USER SYMBOLS
```

Figure 13. 8295 DMA Subroutine

Figure 12 illustrates an 8257/8295 interface and Figure 13 shows example software for handling the system. This software assumes that the 8295 is doing the counting of the transfers hence the Terminal Count of the 8257 DMA channel is loaded with the maximum value while the 8295 receives the actual block size. The 8295 simply stops making requests once the requested number of transfers have been made.

Serial Interface

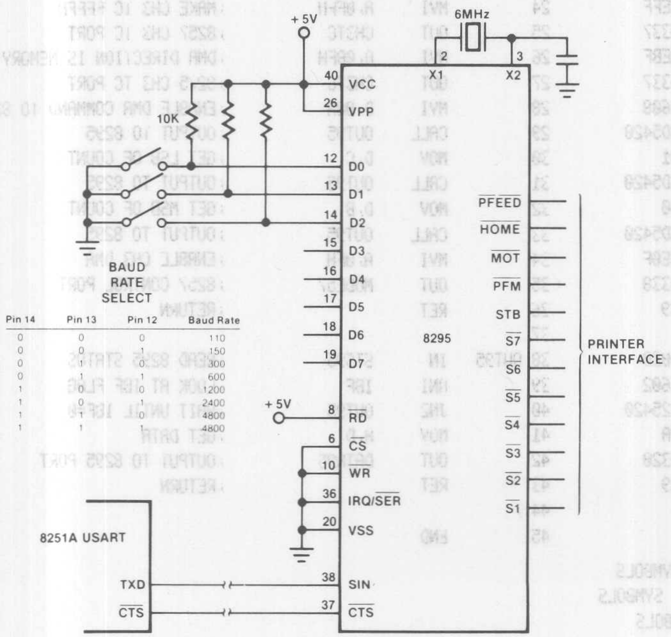
In addition to the parallel interface options, the 8295 supports a "stand-alone" serial interface. In this mode, the only communication with the main processor is via a serial link. This configuration is perfect for remote printer applications; only three wires are required compared to 12 or 13 for the parallel interfaces.

The serial mode is envoked by simply grounding the IRQ/$\overline{\text{SER}}$ pin. See Figure 14. The internal 8295 software interrogates this pin upon power-on and reconfigures the function of several pins if it's grounded. The DACK/SIN pin becomes the serial data input (SIN) and the DRQ/$\overline{\text{CTS}}$ pin becomes the hardware data holdoff, Clear-to-Send. The lower three Data Bus pins become the Baud Rate Select inputs. Note that it is necessary to ground $\overline{\text{CS}}$ and $\overline{\text{WR}}$, and pull $\overline{\text{RD}}$ high. This enables the "input" direction of the Data Bus pins so that the 8295 may read the baud rate. All standard baud rates from 110 to 4800 baud are accommodated.

After power-on the 8295 looks at IRQ/$\overline{\text{SER}}$ and if it's grounded, the data bus pins are read to determine the baud rate. Data from the serial input is requested by lowering $\overline{\text{CTS}}$. $\overline{\text{CTS}}$ stays low until during the eight bit of the serial data character at which point it goes high (inactive). After the character is assembled and interpreted, $\overline{\text{CTS}}$ again goes active to request the next character. The 8295 does not check for parity and characters with invalid start bits or framing errors (stop bit wrong polarity) are ignored. $\overline{\text{CTS}}$ is normally connected to the UART's $\overline{\text{CTS}}$ input. An inactive CTS holds off the UART transmitter from transmitting characters.

In serial mode, the command and data definitions still apply as in parallel mode. Commands and data may be mixed although commands take effect immediately when received.

Figure 15 shows example software to drive an 8251A Programmable Serial Interface when connected to an 8295. This software is similar to Figure 10 except it assumes that the 8251A has the same I/O port addresses as the 8295 had in Figure 9. Note that the TXE (Transmitter Empty) flag is used to load data into the 8251A transmitting both characters in the transmitter (the transmitter is double buffered) if CTS goes inactive. The TXE flag allows only one character at a time in the transmitter so CTS going inactive simply finishes off the current character. The 8295 accepts only one character at a time.



Pin 14	Pin 13	Pin 12	Baud Rate
0	0	0	110
0	0	1	150
0	1	0	300
0	1	1	600
1	0	0	1200
1	0	1	2400
1	1	0	4800
1	1	1	4800

Figure 14. 8295 Serial Interface

```
ASM80 :F1:95F15.SRC TITLE('8295 AP NOTE FIGURE 15')


ISIS-II 8080/8085 MACRO ASSEMBLER, X108        MODULE   PAGE    1
8295 AP NOTE FIGURE 15

  LOC  OBJ          SEQ         SOURCE STATEMENT

                      1 $MOD85
                      2 ;
                      3 ;SYSTEM EQUATES
  20D0                4 PRTSRT  EQU     20D0H           ;POINTER STORAGE
  0004                5 TXE     EQU     04H             ;TXE FLAG MASK
  0031                6 STS51   EQU     31H             ;8251 STATUS REGISTER PORT
  0031                7 DATA51  EQU     31H             ;8251 DATA REGISTER PORT
                      8 ;
  2030                9         ORG     2030H
                     10 ;
                     11 ;PRINT BUFFER OUTPUT SUBROUTINE - THIS ROUTINE PRINTS THE BUFFER
                     12 ;STARTING AT THE POINTER STORED AT PRTSRT.  THE ROUTINE RETURNS WHEN
                     13 ;A 0FFH IS FETCHED FROM THE BUFFER.
                     14 ;
  2030 E5            15 PRINT:  PUSH    H               ;SAVE HL
  2031 C5            16         PUSH    B               ;SAVE BC
  2032 2AD020        17         LHLD    PRTSRT          ;GET BUFFER POINTER
  2035 7E            18 PRT1:   MOV     A,M             ;GET CHARACTER FROM BUFFER
  2036 47            19         MOV     B,A             ;SAVE IT IN B
  2037 FEFF          20         CPI     0FFH            ;IS IT THE BUFFER END?
  2039 CA4A20        21         JZ      PEXIT           ;YES, GO EXIT
  203C DB31          22 PRT2:   IN      STS51           ;NO, READ 8251 STATUS
  203E E604          23         ANI     TXE             ;LOOK AT TXE FLAG
  2040 CA3C20        24         JZ      PRT2            ;WAIT UNTIL TXE=1
  2043 78            25         MOV     A,B             ;RECOVER CHARACTER
  2044 D331          26         OUT     DATA51          ;OUTPUT TO 8251
  2046 23            27         INX     H               ;BUMP BUFFER POINTER
  2047 C33520        28         JMP     PRT1            ;GET NEXT CHARACTER
                     29 ;
  204A C1            30 PEXIT:  POP     B               ;RESTORE BC
  204B E1            31         POP     H               ;RESTORE HL
  204C C9            32         RET                     ;RETURN
                     33 ;
                     34         END

PUBLIC SYMBOLS

EXTERNAL SYMBOLS

USER SYMBOLS
DATA51 A 0031   PEXIT  A 204A   PRINT  A 2030   PRT1   A 2035   PRT2   A 203C   PRTSRT A 20D0   STS51  A 0031
TXE    A 0004

ASSEMBLY COMPLETE, NO ERRORS
```

Figure 15. 8251A Subroutine

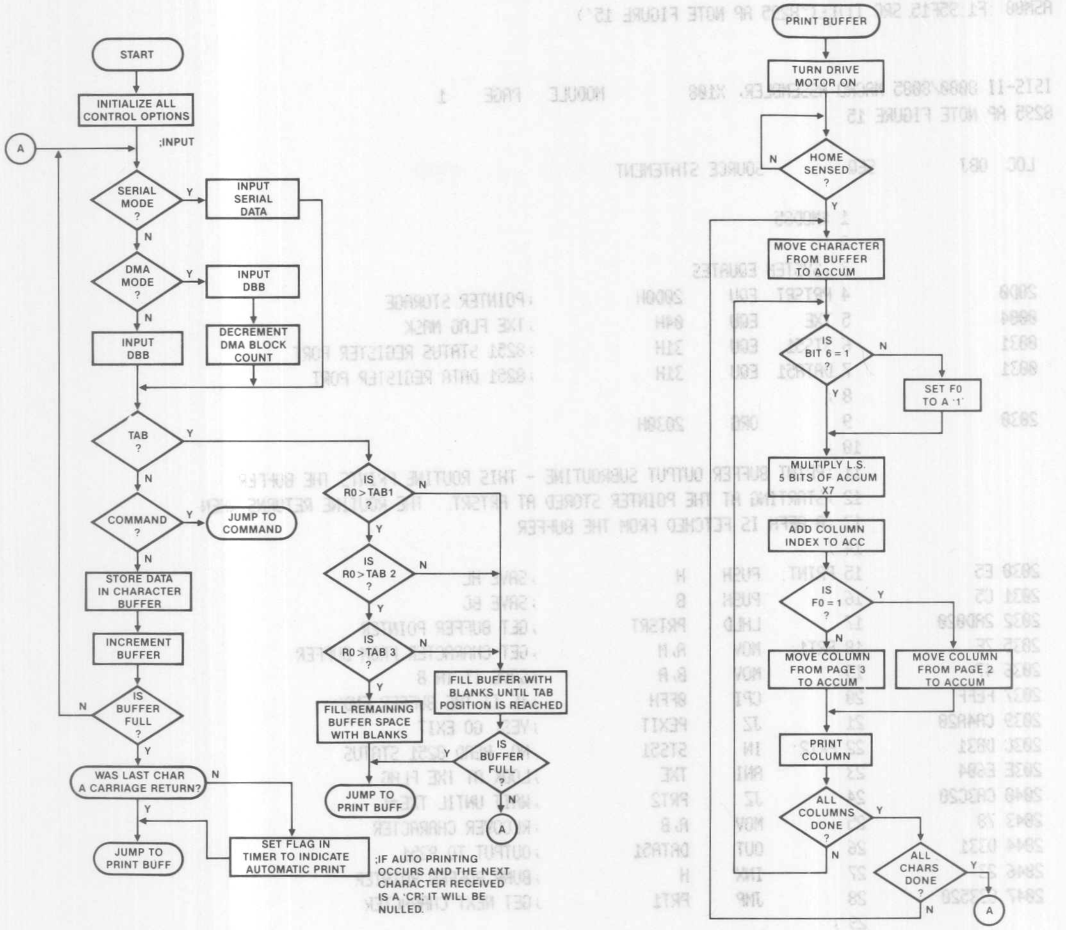


Figure 16. 8295 Flow Chart

8295 SOFTWARE

For those readers using the 8295 as a design example for UPI software, the flow charts for the program are shown in Figure 16 and the 8295 source listing is included as Appendix A. (Machine readable source listings are available through Insite, the Intel User's Library.) As an aid to understanding this software, the following observations can be made:

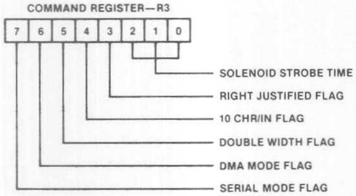
1. The 8295 uses only Register Bank 0. The function of registers R6 and R7 is determined by the mode. In parallel mode they are concantenated to form the 16 bit DMA count register. In serial mode, R6 is a counter during character reception.

2. Characters and commands are input from the Input Data register via the INPUT subroutine. The routine defines the input mode, fetches the data, and stores it in R2. If the DMA mode is enabled, the block count in R6 and R7 is decremented by the DECR routine each time a data transfer occurs until the count is exhausted.

3. Characters are decoded by routine P6A which also detects any illegal characters by the INPUT routine. R0 is assigned as the character buffer pointer and R4 is designated as the buffer size limit. The commands which affect the buffer size will affect R0 and R4.

4. Command characters are decoded by the routine CMD. All command routines are referenced via an indirect jump table. The command routines are easy to understand from the listing hence they are not included in Figure 16 but simply referenced.

5. Register R3 is the bit-oriented command register. Each bit of R3 represents an operating mode. This definition is shown below.



6. After the character buffer has reached its limit (R0 = R4) or a CR character is received, the contents of the buffer are printed. Subroutine PRINT loads R0 with the address of the character to be printed and R2 serves as an index to keep track of the current column within the character. Subroutine CHAR determines which ASCII table is accessed by setting or clearing flag F0.

7. Subroutine XS2 multiples the least significant 5 bits of the ASCII character by 7. The result addresses one of the 32 characters on Page 1 or 2 of the Program Memory ASCII table. The column index, R2, is then added to the result to address the current column. Each character is represented by 7 bytes. R2 indexes thru each byte to select the appropriate solenoid information.

8. Subroutine COL8 fetches the solenoid on-time and off-time constants from a table starting at location 0F8H. The time is represented by a hex number which is used as a loop counter in a software timing loop. No character input is allowed while printing is in progress.

CONCLUSION

The 8295 is an excellent example of what can be done with the UPI-41A family. As a printer controller, it completely relieves the main processor of all the real-time tasks associated with the control of the printer plus valuable system ROM space is not required to store the ASCII-to-dot matrix conversion table or the timing software since it's all done in the 8295 itself. As a UPI design example, the 8295 illustrates the variety of data transfer interfaces available. If the 8295 itself does not fit your printer controller requirements, feel free to modify the 8295 software contained in this application note or that in AP-27 and program your own 8741A.

Appendix A

APPENDIX A

```
ASM48 :F1:8295.SRC
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    1
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ         SOURCE STATEMENT

$MOD42 TITLE('LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE')
;*****************************************************************
;**  8295 - LRC 7040 SERIES PRINTER CONTROLLER                  **
;**      REV.0 FOR 7X7 CHARACTER MATRIX                         **
;*****************************************************************
;COPYRIGHT (C) 1978
;INTEL CORPORATION
;3065 BOWERS AVE.
;SANTA CLARA, CA. 95051
;*****************************************************************
;** PAGE0 CONTAINS THE INITIALIZATION SEQUENCE,THE OUTPUTING **
;** OF DATA TO THE SOLENIODS, THE SERIAL INPUT ROUTINE, THE  **
;** PAPER FEED ROUTINE,AND THE SOLENIOD FIRETIME ROUTINE     **
;*****************************************************************
$EJECT

ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    2
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ         SOURCE STATEMENT

;*****************************************************************
;**                                                              **
;**                       ;REGISTER ASSIGNMENT TABLE             **
;**                                                              **
;*****************************************************************
;**                                                              **
;**                     R0      INPUT BUFFER POINTER             **
;**                     R1      TEMPORARY STORAGE                **
;**                     R2      TEMPORARY STORAGE                **
;**                     R3      COMMAND REGISTER                 **
;**                     R4      BUFFER SIZE                      **
;**                     R5      TEMPORARY STORAGE FOR DELAY ROUTINE **
;**                     R6      LOW ORDER DMA COUNTER            **
;**                     R7      HIGH ORDER DMA COUNTER           **
;**                     TIMER   TEMPORARY STORAGE                **
;**                                                              **
;*****************************************************************
$EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    3
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ        SOURCE STATEMENT

;****************************************************************
;**                                                            **
;**                    RAM ASSIGNMENT TABLE                    **
;**                                                            **
;****************************************************************
;**                                                            **
;**                    RAM ADDRESS           FUNCTION          **
;**                                                            **
;**                    00-07H                REGISTER BANK 1   **
;**                    08-14H                PROGRAM STACK     **
;**                    15-17H                TAB POSITION STORAGE **
;**                    18-40H                CHARACTER BUFFER  **
;**                                                            **
;****************************************************************

$EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    4
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ        SOURCE STATEMENT


;****************************************************************
;**                                                            **
;**                 COMMAND REGISTER DEFINITION                **
;**                                                            **
;****************************************************************
;**                                                            **
;**                 BIT 7   SERIAL MODE FLAG                   **
;**                 BIT 6   DMA MODE FLAG                      **
;**                 BIT 5   DOUBLE WIDE FLAG                   **
;**                 BIT 4   32 COLUMNS/LINE                    **
;**                 BIT 3   RIGHT JUSTIFIED PRINT              **
;**                 BITS 2,1,0 INDICATE SOLENOID ON TIME       **
;**                                                            **
;****************************************************************
$EJECT
```

```
ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    5
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ          SEQ        SOURCE STATEMENT

0000                79          ORG     000H
                    80
                    81
0000 02             82 INIT:    OUT     DBB,A   ;SET OBF
0001 0A             83          IN      A,P2    ;CHECK SERIAL STRAP
0002 B208           84          JB5     PARA
0004 BB83           85          MOV     R3,#83H ;SET SERIAL BIT IN CMD
0006 040E           86          JMP     CLR1
0008 9ABF           87 PARA:    ANL     P2,#0BFH
000A F5             88          EN      FLAGS
000B E5             89          EN      DMA
000C BB03           90          MOV     R3,#03H
000E 27             91 CLR1:    CLR     A       ;CLEAR DMA BUSY FLAG
000F 90             92          MOV     STS,A
0010 BC40           93 CLEAR:   MOV     R4,#40H ;INITIALIZE BUFFER
0012 B818           94 AGAIN:   MOV     R0,#13H ;INITIALIZE POINTER
0014 27             95          CLR     A       ;RESET STACK TO SAVE TABS
0015 D7             96          MOV     PSW,A   ;STACK = 0,ALL FLAGS = 0
0016 3414           97 DECO:    CALL    INPUT
0018 3428           98          CALL    FCA     ;DECODE DATA
001A FC             99          MOV     A,R4
001B D0            100          XRL     A,@R0
001C 9616          101          JNZ     DECO
                   102
001E FB            103 PRINT:   MOV     A,R3
001F C8            104          DEC     R0      ;LOCATE LAST CHARACTER INPUT IF R.J.
0020 7224          105          JB3     ON      ;CHECK FOR RIGHT JUST.
0022 B818          106          MOV     R0,#18H ;PRINT FROM THE ORIGIN
0024 9AEF          107 ON:      ANL     P2,#0EFH        ;TURN DRIVE MOTOR ON
0026 4626          108 NHOME:   JNT1    NHOME   ;WAIT FOR HOME SWITCH
0028 2340          109          MOV     A,#40H  ;STALL
002A 54F8          110          CALL    WAIT
002C BA06          111 XFER:    MOV     R2,#06H ;RJ COL. INDEX
002E FB            112          MOV     A,R3    ;CHECK FOR RJ
002F 7233          113          JB3     CHAR    ;RJ TRUE
0031 BA00          114          MOV     R2,#00H ;INDEX FOR NORM. PRINTING
0033 F0            115 CHAR:    MOV     A,@R0   ;FETCH CHARACTER
0034 85            116          CLR     F0      ;F0 DETERMINES WHICH CHARACTER TABLE
0035 B238          117          JB5     PAGE
0037 95            118          CPL     F0
0038 54E0          119 PAGE:    CALL    XS2     ;FETCH COL. FROM TABLE
003A A9            120          MOV     R1,A
003B FB            121          MOV     A,R3    ;CHECK FOR D.W.
003C B23F          122          JB5     NOTS
003E 95            123          CPL     F0      ;F0 INDICATES D.W. MODE
003F F9            124 NOTS:    MOV     A,R1
0040 147B          125          CALL    FIRE    ;PRINT COL.
0042 FB            126          MOV     A,R3    ;CHECK RJ
0043 724D          127          JB3     RJP
0045 2306          128          MOV     A,#06H
0047 DA            129          XRL     A,R2
0048 1A            130          INC     R2
0049 9633          131          JNZ     CHAR    ;PRINT NEXT COL.
004B 0452          132          JMP     LSTCOL
004D 27            133 RJP:     CLR     A       ;CHECK RJ,FIRE COLS. IN REVERSE ORDER
```

```
LOC  OBJ          SOURCE STATEMENT

004E DA                   XRL    A,R2
004F CA                   DEC    R2
0050 9633                 JNZ    CHAR
0052 B656         LSTCOL: JF0    A4
0054 1480                 CALL   COL8
0056 237F         A4:     MOV    A,#7FH  ;CLEAR STB & DATA PINS
0058 39                   OUTL   P1,A
0059 2319                 MOV    A,#19H
005B 54F8                 CALL   WAIT
005D FB                   MOV    A,R3
005E 7264                 JB3    RJ2
0060 FC                   MOV    A,R4
0061 18                   INC    R0      ;INCR POINTER
0062 0467                 JMP    CK
0064 2317         RJ2:    MOV    A,#17H
0066 C8                   DEC    R0      ;DECR POINTER
0067 D8           CK:     XRL    A,R0
0068 962C                 JNZ    XFER    ;RETURN FOR NEXT CHAR.
006A 566A         HOME:   JT1    HOME    ;SENSE HOME LOW?
006C 2320                 MOV    A,#20H  ;STALL
006E 54F8                 CALL   WAIT
0070 8A10                 ORL    P2,#10H ;STOP DRIVE MOTOR
0072 0412                 JMP    AGAIN   ;NEXT LINE

0074 FB           DMAIN:  MOV    A,R3    ;EXIT IF SERIAL MODE
0075 F27A                 JB7    SERROR  ;SERIAL CMD ERROR
0077 D677         INBUF:  JNIBF  INBUF   ;WAIT FOR DMA PARAMS.
0079 22                   IN     A,DBB
007A 93           SERROR: RETR



007B B67F         FIRE:   JF0    SGLE
007D 09                   IN     A,P1    ;D.W. AND PREVIOUS COL.
007E 59                   ANL    A,R1
007F 39           SGLE:   OUTL   P1,A    ;OUTPUT TO SOL.
0080 FB           COL8:   MOV    A,R3    ;A GETS ON TIME
0081 43F8                 ORL    A,#0F8H
0083 A3                   MOVP   A,@A
0084 530F                 ANL    A,#0FH
0086 8980                 ORL    P1,#80H ;STROBE SOLENOIDS
0088 54F8                 CALL   WAIT
008A 997F                 ANL    P1,#7FH ;DISABLE SOL. STROBE
008C FB                   MOV    A,R3    ;A GET OFF TIME
008D 43F8                 ORL    A,#0F8H
008F A3                   MOVP   A,@A
0090 47                   SWAP   A
0091 530F                 ANL    A,#0FH
0093 2B                   XCH    A,R3
0094 9299                 JB4    C10
0096 2B                   XCH    A,R3
0097 049C                 JMP    CON
0099 2B           C10:    XCH    A,R3
009A 0306                 ADD    A,#06H  ;INCREASE BIAS FOR 10C/I
009C B6A3         CON:    JF0    SING    ;SKIP IF SINGLE
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0                PAGE    7
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

LOC  OBJ          SEQ          SOURCE STATEMENT

009E 0314                    ADD   A,#14H  ;ADD 7 TO OFFTIME IF D.W.
00A0 29                      XCH   A,R1    ;SAVE PREVIOUS COL.
00A1 39                      OUTL  P1,A    ;SAVE PREVIOUS COL.
00A2 29                      XCH   A,R1
00A3 44F8               SING: JMP   WAIT


                        ;********************************************************
                        ;   SERIAL ROUTINE,ASSEMBLES THE DESIRED DATA FROM THE
                        ;   SERIAL INPUT AND PLACE THE DATA IN THE ACCUMULATOR.
                        ;********************************************************

00A5 9ABF               CTS:  ANL   P2,#0BFH  ;REQUEST /CTS
00A7 0A                 ONE:  IN    A,P2    ;LOOP UNTIL START BIT FOUND
00A8 F2A7                     JB7   ONE
00AA B900                     MOV   R1,#0   ;RESET TEMP REG
00AC BA09                     MOV   R2,#09H ;SET INDEX
00AE 09                       IN    A,P1    ;BIAS
00AF 74E0                     CALL  HBIT    ;WAIT 1/2 CYCLE
00B1 0A                       IN    A,P2    ;CHECK FOR START BIT
00B2 F2A7                     JB7   ONE     ;WRONG START BIT
00B4 BE03                     MOV   R6,#03H
00B6 EEB6               LZ:   DJNZ  R6,LZ
00B8 EACE               CONT: DJNZ  R2,LOAD ;LOAD THE EIGHT BITS
00BA 8A40                     ORL   P2,#40H ;DISABLE /CTS
00BC BE06                     MOV   R6,#06H ;BIAS
00BE EEBE               W14:  DJNZ  R6,W14  ;WAIT
00C0 74E0                     CALL  HBIT
00C2 74E0                     CALL  HBIT
00C4 0A                       IN    A,P2
00C5 37                       CPL   A       ;CHECK STOP BIT
00C6 F2A7                     JB7   ONE     ;WRONG STOP BIT
00C8 F9                       MOV   A,R1
00C9 F7                       RLC   A
00CA 537F                     ANL   A,#7FH
00CC AA                       MOV   R2,A
00CD 93                       RETR


00CE 74E0               LOAD: CALL  HBIT    ;DELAY 1 CYCLE
00D0 74E0                     CALL  HBIT
00D2 BE03                     MOV   R6,#03H
00D4 EED4               L1:   DJNZ  R6,L1
00D6 00                       NOP
00D7 0A                       IN    A,P2    ;INPUT SERIAL BIT
00D8 5380                     ANL   A,#80H  ;MASK BIT
00DA 49                       ORL   A,R1    ;ADD PREVIOUS BITS
00DB 67                       RRC   A
00DC A9                       MOV   R1,A
00DD 04B8                     JMP   CONT    ;FINISH JOB

00DF 9AFE               PF:   ANL   P2,#0FEH        ;PF MOTOR ON
00E1 B90A                     MOV   R1,#0AH
00E3 2388               P3C:  MOV   A,#088H
00E5 54F8                     CALL  WAIT
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE   8
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ            SOURCE STATEMENT

00E7 E9E3                DJNZ    R1,P3C
00E9 F8          IT0:    MOV     A,R0    ;DELAY CONTANT =BUFF POINTER (18H TO 40H)
00EA 26EA        IT1:    JNT0    IT1
00EC 54F8                CALL    WAIT    ;DELAY =1MS TO 2.5MS
00EE 36E9                JT0     IT0
00F0 23F3                MOV     A,#0F3H ;STALL
00F2 54F8                CALL    WAIT
00F4 8A01                ORL     P2,#01H ;PF MOTOR OFF
00F6 93          P3F:    RETR

00F8                     ORG     0F8H    ;SOL ON TIME CONSTANTS
00F8 D4                  DB      0D4H    ;200US ON TIME
00F9 C5                  DB      0C5H    ;240
00FA B6                  DB      0B6H    ;280
00FB A7                  DB      0A7H    ;320    ;DEFAULT
00FC 98                  DB      98H     ;360
00FD 89                  DB      89H     ;400
00FE 7A                  DB      7AH     ;440
00FF 6B                  DB      6BH     ;480


                 ;*************************************************************
                 ; PAGE 1 INPUTS, DECODES, AND EXECUTES COMMANDS AND DATA.
                 ;*************************************************************

0100                     ORG     100H
0100 00                  NOP
0101 B5                  DB      (SO1 AND 0FFH)  ;ADDRESS FOR SET OUTPUT 1
0102 B2                  DB      (SO2 AND 0FFH)  ;SO2
0103 BB                  DB      (RO1 AND 0FFH)  ;RO1
0104 B8                  DB      (RO2 AND 0FFH)  ;RO2
0105 BE                  DB      (RESET AND 0FFH)        ;RESET
0106 A8                  DB      (B32 AND 0FFH)  ;B32
0107 E4                  DB      (B40 AND 0FFH)  ;B40
0108 EA                  DB      (DWDE AND 0FFH) ;DWDE
0109 C9                  DB      (SDMA AND 0FFH) ;SDMA
010A A0                  DB      (SSOL AND 0FFH) ;SSOL
010B 88                  DB      (SLF AND 0FFH)  ;SLF
010C 81                  DB      (MLF AND 0FFH)  ;MLF
010D 84                  DB      (TOF AND 0FFH)  ;TOF
010E DE                  DB      (CR AND 0FFH)   ;CR
010F 72                  DB      (T1 AND 0FFH)   ;T1
0110 72                  DB      (T2 AND 0FFH)   ;T2
0111 72                  DB      (T3 AND 0FFH)   ;T3
0112 F9                  DB      (RJ AND 0FFH)   ;RJ
0113 A0                  DB      (SSOL AND 0FFH) ;SSOL



0114 FB          INPUT:  MOV     A,R3
0115 F226                JB7     YME
0117 37                  CPL     A
0118 D21C                JB6     NODECR
011A 8A40                ORL     P2,#40H ;SET DRQ FOR DMA
011C D61C        NODECR: JNIBF   NODECR  ;SHARED BY PARALLEL & DMA
```


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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    9
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ         SOURCE STATEMENT

 011E 22          299         IN     A,DBB
 011F 537F        300         ANL    A,#7FH
 0121 AA          301         MOV    R2,A
 0122 3462        302         CALL   DECR    ;DEC DMA COUNT FOR DMA & PARALLEL
 0124 FA          303         MOV    A,R2    ;DATA STORED IN A & R2
 0125 93          304         RETR           ;RET & RESTORE FLAGS
 0126 04A5        305 YME:    JMP    CTS     ;SERIAL, USE SERIAL INPUT ROUTINE
                  306
 0128 74ED        307 P6A:    CALL   SPCR    ;CHECK FOR SPECIAL CASE CR
 012A D24E        308         JB6    CHECK5
 012C B250        309         JB5    DATA    ;CHECK FOR VALID CHAR.
 012E D309        310         XRL    A,#09H  ;TAB ?
 0130 9656        311         JNZ    CMD     ;COMMAND
 0132 B915        312 TAB:    MOV    R1,#15H ;R1 GETS TAB[I]
 0134 BA03        313         MOV    R2,#03H
 0136 F1          314 P6BB:   MOV    A,@R1   ;CHECK TAB
 0137 F24D        315         JB7    TERROR  ;LIMIT TAB TO BMAX
 0139 D24D        316         JB6    TERROR
 013B 37          317         CPL    A
 013C 17          318         INC    A
 013D 68          319         ADD    A,R0
 013E F1          320         MOV    A,@R1   ;A GET TAB LOC.
 013F E645        321         JNC    P6AA    ;FIND WHICH TAB
 0141 19          322         INC    R1
 0142 EA36        323         DJNZ   R2,P6BB
 0144 FC          324 SPRL:   MOV    A,R4    ;EXCEED ALL TAB, FILL IN BLANKS
 0145 AA          325 P6AA:   MOV    R2,A
 0146 B020        326 RTAB:   MOV    @R0,#20H
 0148 18          327         INC    R0
 0149 FA          328         MOV    A,R2
 014A D8          329         XRL    A,R0    ;FILL IN BLANKS
 014B 9646        330         JNZ    RTAB
 014D 93          331 TERROR: RETR
                  332
 014E B255        333 CHECK5: JB5    SEND
 0150 FA          334 DATA:   MOV    A,R2
 0151 A0          335         MOV    @R0,A
 0152 18          336         INC    R0
 0153 54ED        337         CALL   PEON    ;SET SPECIAL FLAG FOR LAST DATA CHARACTER
 0155 93          338 SEND:   RETR
                  339
 0156 B914        340 CMD:    MOV    R1,#14H ;R1 EQ INDEX
 0158 FA          341 P7C:    MOV    A,R2    ;A GETS CMD
 0159 17          342         INC    A
 015A D9          343         XRL    A,R1
 015B C660        344         JZ     FOUND   ;MATCH ?
 015D E958        345         DJNZ   R1,P7C
 015F 93          346         RETR
                  347
 0160 F9          348 FOUND:  MOV    A,R1
 0161 B3          349         JMPP   @A      ;JUMP INDIRECT TO CMD ROUTINE
                  350
 0162 FE          351 DECR:   MOV    A,R6
 0163 9670        352         JNZ    LARS    ;DEC R6,R7 AS REG. PAIR,RET ON 0
 0165 4F          353         ORL    A,R7
```

```
LOC  OBJ           SOURCE STATEMENT

0166 966F                JNZ     NRST
0168 2B                  XCH     A,R3
0169 53BF                ANL     A,#0BFH
016B 2B                  XCH     A,R3
016C 90                  MOV     STS,A
016D 8A20                ORL     P2,#20H ;ENABLE INTERUPT PIN
016F CF          NRST:   DEC     R7
0170 CE          LAPS:   DEC     R6
0171 93                  RETR


                 ;*******************************
                 ; COMMAND LOOK UP TABLE.
                 ;*******************************


                 T1:     ;A = ADDR OF CMD JUMP IN CMD TABLE
                 T2:     ;A = F.1 OR 0
0172 17          T3:     INC     A       ;A=0,1,OR 2H
0173 5303                ANL     A,#03H  ;MASK SIGNIFICANT BITS
0175 0315                ADD     A,#15H  ;ACCUM = 15,16,OR 17H -(RAM LOCATIONS FOR TABS)
0177 62          STAB:   MOV     T,A     ;TEMP STORAGE FOR TAB
0178 3414                CALL    INPUT
017A 0318                ADD     A,#18H
017C A9                  MOV     P1,A
017D 42                  MOV     A,T
017E 29                  XCH     A,R1
017F A1                  MOV     @R1,A
0180 93                  RETR

0181 85          MLF:    CLR     F0      ;MULTIPLE LINE FEED
0182 248A                JMP     LF

0184 97          TOF:    CLR     C       ;TOP OF FORM
0185 A7                  CPL     C
0186 248A                JMP     LF      ;LFUTF

0188 85          SLF:    CLR     F0      ;SINGLE LINE FEED
0189 95                  CPL     F0
018A F69C        LF:     JC      P12B    ;LFUTOF
018C B693                JF0     P12A    ;SINGLE LF
018E 3414                CALL    INPUT
0190 AA                  MOV     R2,A
0191 C69B                JZ      P12C
0193 14DF        P12A:   CALL    PF
0195 F69C                JC      P12B
0197 B69B                JF0     P12C
0199 EA93                DJNZ    R2,P12A ;DECR. # OF LINES
019B 93          P12C:   RETR
019C 0A          P12B:   IN      A,P2
019D 3293                JB1     P12A
019F 93                  RETR

01A0 3414        SSOL:   CALL    INPUT   ;FETCH SOL. ON TIME
01A2 2B                  XCH     A,R3
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE    11
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ        SOURCE STATEMENT

 01A3 53F8         409        ANL     A,#0F8H ;CLEAR PREV. SOL. TIME
 01A5 6B           410        ADD     A,R3
 01A6 2B           411        XCH     A,R3
 01A7 93           412        RETR
                   413
 01A8 FB           414 B32:   MOV     A,R3    ;32 CHARACTER BUFFER
 01A9 4310         415        ORL     A,#10H
 01AB 53DF         416        ANL     A,#0DFH
 01AD AB           417        MOV     R3,A
 01AE BC39         418        MOV     R4,#39H ;33 CHAR. /LINE
 01B0 0412         419        JMP     AGAIN
                   420
 01B2 8A04         421 SO2:   ORL     P2,#04H ;SET GO2
 01B4 93           422        RETR
                   423
 01B5 8A08         424 SO1:   ORL     P2,#08H ;SET GO1
 01B7 93           425        RETR
                   426
 01B8 9AFB         427 RO2:   ANL     P2,#0FBH        ;RESET GO2
 01BA 93           428        RETR
                   429
 01BB 9AF7         430 RO1:   ANL     P2,#0F7H        ;RESET GO1
 01BD 93           431        RETR
                   432
 01BE 89FF         433 RESET: ORL     P1,#0FFH        ;RESET PORT 1
 01C0 23BF         434        MOV     A,#0BFH
 01C2 3A           435        OUTL    P2,A    ;RESET PORT 2
 01C3 FB           436        MOV     A,R3    ;RESET CMD EXCEPT FOR SERIAL & SOL
 01C4 5387         437        ANL     A,#87H
 01C6 AB           438        MOV     R3,A
 01C7 040E         439        JMP     CLR1    ;CLEAR STS & RESET STACK
 01C9 1474         440 SDMA:  CALL    DMAIN
 01CB AE           441        MOV     R6,A    ;LOAD DMA COUNTERS
 01CC 1474         442        CALL    DMAIN
 01CE 9ADF         443        ANL     P2,#0DFH        ;CLEAR INT PIN
 01D0 AF           444        MOV     R7,A
 01D1 4E           445        ORL     A,R6
 01D2 C662         446        JZ      DECR
 01D4 3462         447        CALL    DECR
 01D6 2B           448        XCH     A,R3
 01D7 4340         449        ORL     A,#40H  ;SET DMA FLAG
 01D9 2B           450        XCH     A,R3
 01DA 2310         451        MOV     A,#10H  ;SET FLAG FOR TELL HOST DMA ON
 01DC 90           452        MOV     STS,A
 01DD 93           453        RETR
                   454
 01DE 42           455 CR:    MOV     A,T     ;CHECK BMAX+1 FLAG
 01DF D30D         456        XRL     A,#0DH  ;IF BUFF. PRINTED AUTO,NO CR
 01E1 9644         457        JNZ     SPRL
 01E3 93           458        RETR
                   459
                   460
 01E4 FB           461 B40:   MOV     A,R3    ;40 CHARACTER BUFFER
 01E5 53CF         462        ANL     A,#0CFH
 01E7 AB           463        MOV     R3,A
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0          PAGE  12
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

LOC  OBJ        SEQ       SOURCE STATEMENT

01E8 0410                      JMP    CLEAR



01EA 2320           DWDE:      MOV    A,#20H  ;DOUBLE WIDE PRINT MODE
01EC 4B                        ORL    A,R3    ;SET DW BIT
01ED AB                        MOV    R3,A
01EE B818                      MOV    R0,#18H ;CLEAR BUFFER POINTER
01F0 FC                        MOV    A,R4
01F1 D2F6                      JB6    X0
01F3 BC2A                      MOV    R4,#2AH ;32 CHAR. BUFFER
01F5 93                        RETR
01F6 BC2C           X0:        MOV    R4,#2CH ;40 CHAR. BUFFER
01F8 93                        RETR

01F9 FB             RJ:        MOV    A,R3    ;SET RJ BIT IN CMD
01FA 4308                      ORL    A,#08H
01FC AB                        MOV    R3,A
01FD 93                        RETR



                    ;*******************************************************
                    ;  HBIT SUBR. AND THE DATA CONSTANTS ARE IN PAGE 3
                    ;*******************************************************

03E0                           ORG    3E0H

03E0 22             HBIT:      IN     A,DBB   ;CHECK DBB FOR BUAD RATE
03E1 43F8                      ORL    A,#0F8H
03E3 A3                        MOVP   A,@A
03E4 AE                        MOV    R6,A
03E5 BF03           LOOP1:     MOV    R7,#03H ;25US PER LOOP PAIR
03E7 EFE7           LOOP2:     DJNZ   R7,LOOP2
03E9 EEE5                      DJNZ   R6,LOOP1
03EB 0A                        IN     A,P2
03EC 93                        RETR

03ED D30D           SPCR:      XRL    A,#0DH  ;CHECK CR FLAG,EXIT IF TRUE
03EF 96F5                      JNZ    XCR
03F1 34DE                      CALL   CR
03F3 BAFF                      MOV    R2,#0FFH      ;DO NOT EXECUTE CR TWICE
03F5 FA             XCR:       MOV    A,R2
03F6 62                        MOV    T,A
03F7 93                        RETR

03F8                           ORG    3F8H

03F8 B2                        DB     0B2H    ;110 BAUD
03F9 84                        DB     084H    ,150
03FA 40                        DB     40H     ;300
03FB 1F                        DB     1FH     ;600
03FC 0E                        DB     0EH     ;1200
03FD 06                        DB     06H     ;2400
03FE 02                        DB     02H     ;4800
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2 0        PAGE  13
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ        SEQ       SOURCE STATEMENT

03FF 02          519        DB     02H      ;4800
                 520
                 521 ;*************************************************************
                 522 ;   OTHER THAN CHAR TABLE, WAIT AND XS2 ROUTINES EXISTIN PAGE2
                 523 ;*************************************************************
                 524
02E0             525        ORG    2E0H
02E0 531F        526 XS2    ANL    A,#1FH   ;FIND & ADJUST CHARACTER INDEX
02E2 A9          527        MOV    R1,A     ;MULTIPLY INDEX BY 7
02E3 E7          528        RL     A
02E4 E7          529        RL     A
02E5 69          530        ADD    A,R1
02E6 69          531        ADD    A,R1
02E7 69          532        ADD    A,R1
02E8 6A          533        ADD    A,R2     ;ADD COLUMN INDEX TO CHARACTER INDEX
02E9 B6F5        534        JF0    PAGE3
02EB E3          535        MOVP3  A,@A
02EC 83          536        RET
02ED FC          537 PEON:  MOV    A,R4     ;SET SPECIAL OR FLAG IF LAST CHAR IS DATA
02EE D8          538        XRL    A,R0
02EF 96F4        539        JNZ    FSPA
02F1 230D        540        MOV    A,#0DH
02F3 62          541        MOV    T,A
02F4 93          542 FSPA:  RETR
                 543
                 544
02F5 A3          545 PAGE3: MOVP   A,@A
02F6 85          546        CLR    F0
02F7 83          547        RET
02F8 BD06        548 WAIT:  MOV    R5,#06H
02FA EDFA        549 CONX:  DJNZ   R5,CONX  ;40US PER COUNT OF ACC
02FC 07          550        DEC    A
02FD 96F8        551        JNZ    WAIT
02FF 93          552        RETR
                 553
                 554
                 555
                 556 ;**********************************************
                 557 ;   CHARACTER TABLE IN PAGE 2
                 558 ;   MSB IS IGNORED.DATA INVERTED
                 559 ;     SEE EXAMPLE (A)
                 560 ;**********************************************
                 561
0200             562        ORG    200H
                 563
0200 41          564        DB     41H      ;@
0201 3F          565        DB     3FH
0202 62          566        DB     62H
0203 3F          567        DB     3FH
0204 62          568        DB     62H
0205 3F          569        DB     3FH
0206 43          570        DB     43H
                 571
0207 70          572        DB     70H      ;A      ----****
0208 6F          573        DB     6FH      ;       ---*---
```

```
LOC  OBJ        SEQ        SOURCE STATEMENT

0209 5B         574        DB      5BH     ;     --*----*-
020A 3F         575        DB      3FH     ;      -*------
020B 5B         576        DB      5BH     ;     --*----*-
020C 6F         577        DB      6FH     ;     ---*-----
020D 70         578        DB      70H     ;     ----****
                579
020E 3E         580        DB      3EH     ;B
020F 41         581        DB      41H
0210 3E         582        DB      3EH
0211 77         583        DB      77H
0212 3E         584        DB      3EH
0213 77         585        DB      77H
0214 49         586        DB      49H
                587
0215 41         588        DB      41H     ;C
0216 3E         589        DB      3EH
0217 7F         590        DB      7FH
0218 3E         591        DB      3EH
0219 7F         592        DB      7FH
021A 3E         593        DB      3EH
021B 5D         594        DB      5DH
                595
021C 3E         596        DB      3EH     ;D
021D 41         597        DB      41H
021E 3E         598        DB      3EH
021F 7F         599        DB      7FH
0220 3E         600        DB      3EH
0221 7F         601        DB      7FH
0222 41         602        DB      41H
                603
0223 00         604        DB      00H     ;E
0224 7F         605        DB      7FH
0225 36         606        DB      36H
0226 7F         607        DB      7FH
0227 36         608        DB      36H
0228 7F         609        DB      7FH
0229 3E         610        DB      3EH
                611
022A 00         612        DB      00H     ;F
022B 7F         613        DB      7FH
022C 37         614        DB      37H
022D 7F         615        DB      7FH
022E 37         616        DB      37H
022F 7F         617        DB      7FH
0230 3F         618        DB      3FH
                619
0231 41         620        DB      41H     ;G
0232 3E         621        DB      3EH
0233 7F         622        DB      7FH
0234 3E         623        DB      3EH
0235 7B         624        DB      7BH
0236 3E         625        DB      3EH
0237 59         626        DB      59H
                627
0238 00         628        DB      00H
```

LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

```
LOC  OBJ        SEQ        SOURCE STATEMENT

0239 7F         629        DB      7FH     ;H
023A 77         630        DB      77H
023B 7F         631        DB      7FH
023C 77         632        DB      77H
023D 7F         633        DB      7FH
023E 00         634        DB      00H
                635
023F 7F         636        DB      7FH     ;I
0240 3E         637        DB      3EH
0241 7F         638        DB      7FH
0242 00         639        DB      00H
0243 7F         640        DB      7FH
0244 3E         641        DB      3EH
0245 7F         642        DB      7FH
                643
0246 7D         644        DB      7DH     ;J
0247 7E         645        DB      7EH
0248 7F         646        DB      7FH
0249 7E         647        DB      7EH
024A 7F         648        DB      7FH
024B 7E         649        DB      7EH
024C 01         650        DB      01H
                651
024D 00         652        DB      00H     ;K
024E 7F         653        DB      7FH
024F 6F         654        DB      6FH
0250 77         655        DB      77H
0251 5B         656        DB      5BH
0252 7D         657        DB      7DH
0253 3E         658        DB      3EH
                659
0254 00         660        DB      00H
0255 7F         661        DB      7FH
0256 7E         662        DB      7EH     ;L
0257 7F         663        DB      7FH
0258 7E         664        DB      7EH
0259 7F         665        DB      7FH
025A 7E         666        DB      7EH
                667
025B 40         668        DB      40H     ;M
025C 3F         669        DB      3FH
025D 5F         670        DB      5FH
025E 67         671        DB      67H
025F 5F         672        DB      5FH
0260 3F         673        DB      3FH
0261 40         674        DB      40H
                675
0262 20         676        DB      20H
0263 5F         677        DB      5FH     ;N
0264 6F         678        DB      6FH
0265 77         679        DB      77H
0266 7B         680        DB      7BH
0267 7D         681        DB      7DH
0268 02         682        DB      02H
                683
```


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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0    PAGE  16
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ      SEQ      SOURCE STATEMENT

0269 41        684       DB     41H   ;O
026A 3E        685       DB     3EH
026B 7F        686       DB     7FH
026C 3E        687       DB     3EH
026D 7F        688       DB     7FH
026E 3E        689       DB     3EH
026F 41        690       DB     41H
               691
0270 00        692       DB     00H
0271 7F        693       DB     7FH   ;P
0272 37        694       DB     37H
0273 7F        695       DB     7FH
0274 37        696       DB     37H
0275 7F        697       DB     7FH
0276 4F        698       DB     4FH
               699
0277 41        700       DB     41H   ;Q
0278 3E        701       DB     3EH
0279 7F        702       DB     7FH
027A 3F        703       DB     3FH
027B 7A        704       DB     7AH
027C 3D        705       DB     3DH
027D 42        706       DB     42H
               707
027E 00        708       DB     00H   ;R
027F 7F        709       DB     7FH
0280 37        710       DB     37H
0281 7F        711       DB     7FH
0282 33        712       DB     33H
0283 7D        713       DB     7DH
0284 4E        714       DB     4EH
               715
0285 4D        716       DB     4DH   ;S
0286 36        717       DB     36H
0287 7F        718       DB     7FH
0288 36        719       DB     36H
0289 7F        720       DB     7FH
028A 36        721       DB     36H
028B 59        722       DB     59H
               723
028C 3F        724       DB     3FH
028D 7F        725       DB     7FH
028E 3F        726       DB     3FH
028F 40        727       DB     40H   ;T
0290 3F        728       DB     3FH
0291 7F        729       DB     7FH
0292 3F        730       DB     3FH
               731
0293 01        732       DB     01H   ;U
0294 7E        733       DB     7EH
0295 7F        734       DB     7FH
0296 7E        735       DB     7EH
0297 7F        736       DB     7FH
0298 7E        737       DB     7EH
0299 01        738       DB     01H
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0    PAGE  17
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ      SEQ      SOURCE STATEMENT

               739
029A 07        740       DB     07H   ;V
029B 7B        741       DB     7BH
029C 7D        742       DB     7DH
029D 7E        743       DB     7EH
029E 7D        744       DB     7DH
029F 7B        745       DB     7BH
02A0 07        746       DB     07H
               747
02A1 01        748       DB     01H
02A2 7E        749       DB     7EH
02A3 7D        750       DB     7DH
02A4 73        751       DB     73H
02A5 7D        752       DB     7DH
02A6 7E        753       DB     7EH   ;W
02A7 01        754       DB     01H
               755
02A8 3E        756       DB     3EH   ;X
02A9 5D        757       DB     5DH
02AA 6B        758       DB     6BH
02AB 77        759       DB     77H
02AC 6B        760       DB     6BH
02AD 5D        761       DB     5DH
02AE 3E        762       DB     3EH
               763
02AF 3F        764       DB     3FH   ;Y
02B0 5F        765       DB     5FH
02B1 6F        766       DB     6FH
02B2 70        767       DB     70H
02B3 6F        768       DB     6FH
02B4 5F        769       DB     5FH
02B5 3F        770       DB     3FH
               771
02B6 3E        772       DB     3EH
02B7 7D        773       DB     7DH   ;Z
02B8 3A        774       DB     3AH
02B9 77        775       DB     77H
02BA 2E        776       DB     2EH
02BB 5F        777       DB     5FH
02BC 3E        778       DB     3EH
               779
02BD 00        780       DB     00H   ;[
02BE 7F        781       DB     7FH
02BF 3E        782       DB     3EH
02C0 7F        783       DB     7FH
02C1 3E        784       DB     3EH
02C2 7F        785       DB     7FH
02C3 7F        786       DB     7FH
               787
02C4 3F        788       DB     3FH   ;\
02C5 5F        789       DB     5FH
02C6 6F        790       DB     6FH
02C7 77        791       DB     77H
02C8 7B        792       DB     7BH
02C9 7D        793       DB     7DH
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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0      PAGE  18
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ      SOURCE STATEMENT

 02CA 7E          794        DB     7EH
                  795
 02CB 7F          796        DB     7FH       ;]
 02CC 7F          797        DB     7FH
 02CD 3E          798        DB     3EH
 02CE 7F          799        DB     7FH
 02CF 3E          800        DB     3EH
 02D0 7F          801        DB     7FH
 02D1 00          802        DB     00H
                  803
 02D2 77          804        DB     77H       ;^
 02D3 6F          805        DB     6FH
 02D4 5F          806        DB     5FH
 02D5 20          807        DB     20H
 02D6 5F          808        DB     5FH
 02D7 6F          809        DB     6FH
 02D8 77          810        DB     77H
                  811
 02D9 7E          812        DB     7EH       ;_
 02DA 7F          813        DB     7FH
 02DB 7E          814        DB     7EH
 02DC 7F          815        DB     7FH
 02DD 7E          816        DB     7EH
 02DE 7F          817        DB     7FH
 02DF 7E          818        DB     7EH
                  819
                  820
                  821
                  822 ;*************************************
                  823 ;   CHAR. TABLE ON PAGE 3
                  824 ;   MSB IS IGNORED,DATA INVERTED
                  825 ;   SEE EXAMPLE (A) IN PAGE 2 OF ROM
                  826 ;*************************************
                  827
 0300             828        ORG    300H
                  829
 0300 7F          830        DB     7FH       ;BLANK
 0301 7F          831        DB     7FH
 0302 7F          832        DB     7FH
 0303 7F          833        DB     7FH
 0304 7F          834        DB     7FH
 0305 7F          835        DB     7FH
 0306 7F          836        DB     7FH
                  837
 0307 7F          838        DB     7FH       ;!
 0308 7F          839        DB     7FH
 0309 7F          840        DB     7FH
 030A 02          841        DB     02H
 030B 7F          842        DB     7FH
 030C 7F          843        DB     7FH
 030D 7F          844        DB     7FH
                  845
 030E 7F          846        DB     7FH       ;"
 030F 7F          847        DB     7FH
 0310 0F          848        DB     0FH
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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0      PAGE  19
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ         SEQ      SOURCE STATEMENT

 0311 7F          849        DB     7FH
 0312 0F          850        DB     0FH
 0313 7F          851        DB     7FH
 0314 7F          852        DB     7FH
                  853
 0315 6B          854        DB     6BH       ;#
 0316 7F          855        DB     7FH
 0317 00          856        DB     00H
 0318 7F          857        DB     7FH
 0319 00          858        DB     00H
 031A 7F          859        DB     7FH
 031B 6B          860        DB     6BH
                  861
 031C 4D          862        DB     4DH       ;$
 031D 36          863        DB     36H
 031E 7F          864        DB     7FH
 031F 00          865        DB     00H
 0320 7F          866        DB     7FH
 0321 36          867        DB     36H
 0322 59          868        DB     59H
                  869
 0323 0E          870        DB     0EH       ;%
 0324 7D          871        DB     7DH
 0325 0B          872        DB     0BH
 0326 77          873        DB     77H
 0327 68          874        DB     68H
 0328 5F          875        DB     5FH
 0329 38          876        DB     38H
                  877
 032A 49          878        DB     49H       ;&
 032B 36          879        DB     36H
 032C 7F          880        DB     7FH
 032D 37          881        DB     37H
 032E 5A          882        DB     5AH
 032F 7D          883        DB     7DH
 0330 72          884        DB     72H
                  885
 0331 7F          886        DB     7FH       ;'
 0332 7F          887        DB     7FH
 0333 7F          888        DB     7FH
 0334 0F          889        DB     0FH
 0335 7F          890        DB     7FH
 0336 7F          891        DB     7FH
 0337 7F          892        DB     7FH
                  893
 0338 7F          894        DB     7FH       ;(
 0339 63          895        DB     63H
 033A 5D          896        DB     5DH
 033B 3E          897        DB     3EH
 033C 7F          898        DB     7FH
 033D 7F          899        DB     7FH
 033E 7F          900        DB     7FH
                  901
 033F 7F          902        DB     7FH       ;)
 0340 7F          903        DB     7FH
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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0    PAGE  20
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ        SEQ        SOURCE STATEMENT

 0341 7F          904        DB     7FH
 0342 3E          905        DB     3EH
 0343 5D          906        DB     5DH
 0344 63          907        DB     63H
 0345 7F          908        DB     7FH
                  909
 0346 77          910        DB     77H     ;*
 0347 5D          911        DB     5DH
 0348 6B          912        DB     6BH
 0349 14          913        DB     14H
 034A 6B          914        DB     6BH
 034B 5D          915        DB     5DH
 034C 77          916        DB     77H
                  917
 034D 77          918        DB     77H     ;+
 034E 7F          919        DB     7FH
 034F 77          920        DB     77H
 0350 49          921        DB     49H
 0351 77          922        DB     77H
 0352 7F          923        DB     7FH
 0353 77          924        DB     77H
                  925
 0354 7F          926        DB     7FH     ;,
 0355 7F          927        DB     7FH
 0356 7F          928        DB     7FH
 0357 7E          929        DB     7EH
 0358 79          930        DB     79H
 0359 7F          931        DB     7FH
 035A 7F          932        DB     7FH
                  933
 035B 7B          934        DB     7BH     ;-
 035C 7F          935        DB     7FH
 035D 7B          936        DB     7BH
 035E 7F          937        DB     7FH
 035F 7B          938        DB     7BH
 0360 7F          939        DB     7FH
 0361 7B          940        DB     7BH
                  941
 0362 7F          942        DB     7FH     ;.
 0363 7F          943        DB     7FH
 0364 7F          944        DB     7FH
 0365 7E          945        DB     7EH
 0366 7F          946        DB     7FH
 0367 7F          947        DB     7FH
 0368 7F          948        DB     7FH
                  949
 0369 7E          950        DB     7EH     ;/
 036A 7D          951        DB     7DH
 036B 7B          952        DB     7BH
 036C 77          953        DB     77H
 036D 6F          954        DB     6FH
 036E 5F          955        DB     5FH
 036F 3F          956        DB     3FH
                  957
 0370 41          958        DB     41H     ;0
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0    PAGE  21
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ        SEQ        SOURCE STATEMENT

 0371 7F          959        DB     7FH
 0372 3A          960        DB     3AH
 0373 77          961        DB     77H
 0374 2E          962        DB     2EH
 0375 7F          963        DB     7FH
 0376 41          964        DB     41H
                  965
 0377 7F          966        DB     7FH     ;1
 0378 5E          967        DB     5EH
 0379 7F          968        DB     7FH
 037A 00          969        DB     00H
 037B 7F          970        DB     7FH
 037C 7E          971        DB     7EH
 037D 7F          972        DB     7FH
                  973
 037E 5C          974        DB     5CH     ;2
 037F 3B          975        DB     3BH
 0380 7E          976        DB     7EH
 0381 37          977        DB     37H
 0382 7E          978        DB     7EH
 0383 37          979        DB     37H
 0384 4E          980        DB     4EH
                  981
 0385 3D          982        DB     3DH     ;3
 0386 7E          983        DB     7EH
 0387 2F          984        DB     2FH
 0388 7E          985        DB     7EH
 0389 2F          986        DB     2FH
 038A 56          987        DB     56H
 038B 39          988        DB     39H
                  989
 038C 7B          990        DB     7BH     ;4
 038D 77          991        DB     77H
 038E 6B          992        DB     6BH
 038F 5F          993        DB     5FH
 0390 20          994        DB     20H
 0391 7F          995        DB     7FH
 0392 7B          996        DB     7BH
                  997
 0393 0D          998        DB     0DH     ;5
 0394 7E          999        DB     7EH
 0395 2F         1000        DB     2FH
 0396 7E         1001        DB     7EH
 0397 3F         1002        DB     3FH
 0398 6E         1003        DB     6EH
 0399 31         1004        DB     31H
                 1005
 039A 79         1006        DB     79H     ;6
 039B 76         1007        DB     76H
 039C 6F         1008        DB     6FH
 039D 56         1009        DB     56H
 039E 3F         1010        DB     3FH
 039F 76         1011        DB     76H
 03A0 79         1012        DB     79H
                 1013
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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0                PAGE  22
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ       SEQ       SOURCE STATEMENT

03A1 3F         1014      DB     3FH      ;7
03A2 7F         1015      DB     7FH
03A3 38         1016      DB     38H
03A4 77         1017      DB     77H
03A5 2F         1018      DB     2FH
03A6 5F         1019      DB     5FH
03A7 3F         1020      DB     3FH
                1021
03A8 49         1022      DB     49H      ;8
03A9 36         1023      DB     36H
03AA 7F         1024      DB     7FH
03AB 36         1025      DB     36H
03AC 7F         1026      DB     7FH
03AD 36         1027      DB     36H
03AE 49         1028      DB     49H
                1029
03AF 4F         1030      DB     4FH      ;9
03B0 37         1031      DB     37H
03B1 7F         1032      DB     7FH
03B2 36         1033      DB     36H
03B3 7D         1034      DB     7DH
03B4 3B         1035      DB     3BH
03B5 47         1036      DB     47H
                1037
03B6 7F         1038      DB     7FH
03B7 7F         1039      DB     7FH      ;:
03B8 7F         1040      DB     7FH
03B9 6B         1041      DB     6BH
03BA 7F         1042      DB     7FH
03BB 7F         1043      DB     7FH
03BC 7F         1044      DB     7FH
                1045
03BD 7F         1046      DB     7FH      ;;
03BE 7F         1047      DB     7FH
03BF 7E         1048      DB     7EH
03C0 69         1049      DB     69H
03C1 7F         1050      DB     7FH
03C2 7F         1051      DB     7FH
03C3 7F         1052      DB     7FH
                1053
03C4 7F         1054      DB     7FH      ;<
03C5 77         1055      DB     77H
03C6 6B         1056      DB     6BH
03C7 5D         1057      DB     5DH
03C8 3E         1058      DB     3EH
03C9 7F         1059      DB     7FH
03CA 7F         1060      DB     7FH
                1061
03CB 6B         1062      DB     6BH      ;=
03CC 7F         1063      DB     7FH
03CD 6B         1064      DB     6BH
03CE 7F         1065      DB     7FH
03CF 6B         1066      DB     6BH
03D0 7F         1067      DB     7FH
03D1 6B         1068      DB     6BH
```

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ISIS-II MCS-48/UPI-41 MACRO ASSEMBLER, V2.0                PAGE  23
LRC 7040 SERIES PRINTER CONTROLLER SOURCE CODE

 LOC  OBJ       SEQ       SOURCE STATEMENT

                1069
03D2 7F         1070      DB     7FH      ;>
03D3 7F         1071      DB     7FH
03D4 3E         1072      DB     3EH
03D5 5D         1073      DB     5DH
03D6 6B         1074      DB     6BH
03D7 77         1075      DB     77H
03D8 7F         1076      DB     7FH
                1077
03D9 7F         1078      DB     7FH      ;?
03DA 5F         1079      DB     5FH
03DB 3F         1080      DB     3FH
03DC 7A         1081      DB     7AH
03DD 37         1082      DB     37H
03DE 4F         1083      DB     4FH
03DF 7F         1084      DB     7FH
                1085
                1086      END
```

```
USER SYMBOLS
A4     0056   AGAIN  0012   B32    01A8   B40    01E4   C10    0099   CHAR   0033   CHECK5 014E   CK     0067
CLEAR  0010   CLR1   000E   CMD    0156   COL8   0080   CON    009C   CONT   00B8   CONX   02FA   CR     01DE
CTS    00A5   DATA   0150   DECO   0016   DECR   0162   DMAIN  0074   DWDE   01EA   FIRE   007B   FOUND  0160
FSPA   02F4   HBIT   03E0   HOME   006A   INBUF  0077   INIT   0000   INPUT  0114   I10    00E9   IT1    00EA
L1     00D4   LARS   0170   LF     018A   LOAD   00CE   LOOP1  03E5   LOOP2  03E7   LSTCOL 0052   LZ     00B6
MLF    0181   NHOME  0026   NODECR 011C   NOTS   003F   NRST   016F   ON     0024   ONE    00A7   P12A   0193
P12B   019C   P12C   019B   P3C    00E3   P3F    00F6   P6A    0128   P6AA   0145   P6BB   0136   P7C    0158
PAGE   0038   PAGE3  02F5   PARA   0008   PEON   02ED   PF     00DF   PRINT  001E   RESET  01BE   RJ     01F9
RJ2    0064   RJP    004D   RO1    01BB   RO2    01B8   RTAB   0146   SDMA   01C9   SEND   0155   SERROR 007A
SGLE   007F   SING   00A3   SLF    0183   SO1    01B5   SO2    01B2   SPCR   03ED   SPRL   0144   SSOL   01A0
STAB   0177   T1     0172   T2     0172   T3     0172   TAB    0132   TERROR 014D   TOF    0184   W14    00BE
WAIT   02F8   X0     01F6   XCR    03F5   XFER   002C   XS2    02E0   YME    0126

ASSEMBLY COMPLETE, NO ERRORS
```

An 8741A/8041A Digital Cassette Controller

Contents

INTRODUCTION

The microcomputer system designer requiring a low-cost, non-volatile storage medium has a difficult choice. His options have been either relatively expensive, as with floppy discs and bubble memories, or non-transportable, like battery backed-up RAMs. The full-sized digital cassette option was open but many times it too was too expensive for the application. Filling this void of low-cost storage is the recently developed digital mini-cassette. These mini-cassettes are similar to, but not compatible with, dictation cassettes. The mini-cassette transports are inexpensive (well under $100 in quantity), small (less than 25 cu. in.), low-power (one watt), and their storage capacity is a respectable 200K bytes of unformatted data on a 100-foot tape. These characteristics make the mini-cassette perfect for applications ranging from remote datalogging to program storage for hobbyist systems.

The only problem associated with mini-cassette drives is controlling them. While these drives are relatively easy to interface to a microcomputer system, via a parallel I/O port, they can quickly overburden a CPU if other concurrent or critical real-time I/O is required. The cleanest and probably the least expensive solution in terms of development cost is to use a dedicated single-chip controller. However, a quick search through the literature turns up no controllers compatible with these new transports. What to do? Enter the UPI-41A family of Universal Peripheral Interfaces.

The UPI-41A family is a group of two user-programmable slave microcomputers plus a companion I/O expander. The 8741A is the "flag-chip" of the line. It is a complete microcomputer with 1024 bytes of EPROM program memory, 64 bytes of RAM data memory, 16 individually programmable I/O lines, an 8-bit event counter and timer, and a complete slave peripheral interface with two interrupts and Direct Memory Access (DMA) control. The 8041A is the masked ROM, pin compatible version of the 8741A. Figure 2 shows a block diagram common to both parts. The 8243 I/O port expander completes the family. Each 8243 provides 16 programmable I/O lines.

Using the UPI concept, the designer can develop a custom peripheral control processor for his particular I/O problem. The designer simply develops his peripheral control algorithm using the UPI-41A assembly language and programs the EPROM of

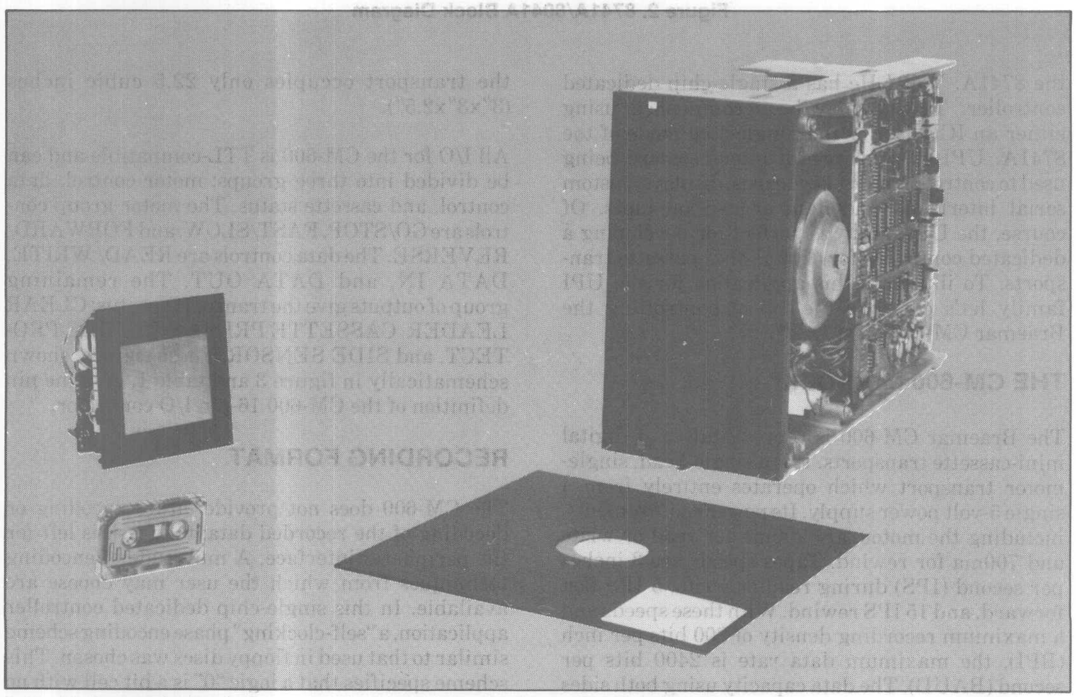

Figure 1. Comparison of Mini-Cassette and Floppy Disk Transports and Media.

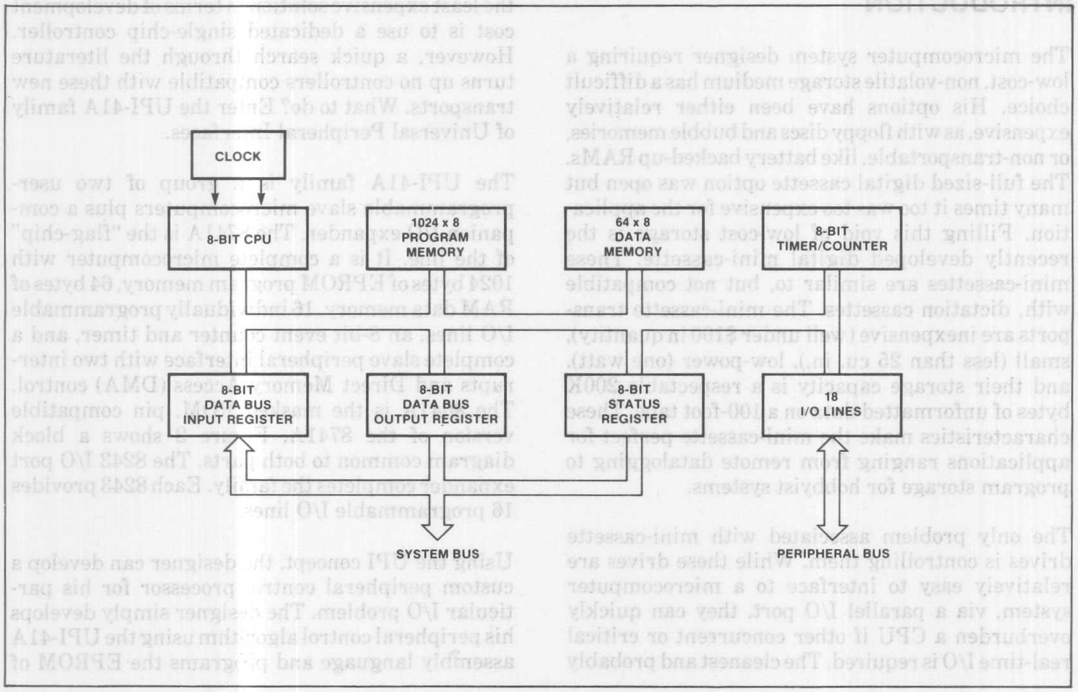

Figure 2. 8741A/8041A Block Diagram

the 8741A. Voila! He has a single-chip dedicated controller. Testing may be accomplished using either an ICE-41A or the Single-step mode of the 8741A. UPI-41A peripheral interfaces are being used to control printers, keyboards, displays, custom serial interfaces, and data encryption units. Of course, the UPI family is perfect for developing a dedicated controller for digital mini-cassette transports. To illustrate this application for the UPI family let's consider the job of controlling the Braemar CM-600 Mini-Dek®.

THE CM-600 MINI-DEK®

The Braemar CM-600 is representative of digital mini-cassette transports. It is a single-head, single-motor transport which operates entirely from a single 5-volt power supply. Its power requirements, including the motor, are 200ma for read or write and 700ma for rewind. Tapes speeds are 3 inches per second (IPS) during read or write, 5 IPS fast forward, and 15 IPS rewind. With these speeds and a maximum recording density of 800 bits per inch (BPI), the maximum data rate is 2400 bits per second (BAUD). The data capacity using both sides of a 100-foot tape is 200K bytes. On top of this, the transport occupies only 22.5 cubic inches (3″x3″x2.5″).

All I/O for the CM-600 is TTL-compatible and can be divided into three groups: motor control, data control, and cassette status. The motor group controls are GO/STOP, FAST/SLOW, and FORWARD/REVERSE. The data controls are READ/ WRITE, DATA IN, and DATA OUT. The remaining group of outputs give the transport's status: CLEAR LEADER, CASSETTE PRESENCE, FILE PROTECT, and SIDE SENSOR. These signals, shown schematically in figure 3 and table 1, give the pin definition of the CM-600 16-pin I/O connector.

RECORDING FORMAT

The CM-600 does not provide either encoding or decoding of the recorded data; that task is left for the peripheral interface. A multitude of encoding techniques from which the user may choose are available. In this single-chip dedicated controller application, a "self-clocking" phase encoding scheme similar to that used in floppy discs was chosen. This scheme specifies that a logic "0" is a bit cell with no transition; a cell with a transition is a logic "1."

Table 1. CM-600 I/O Pin Definition

Pin	I/O	Function
1	—	Index pin—not used
2	—	Signal ground
3	O	Cassette side (0—side B, 1—side A)
4	I	Data input (0—space, 1—mark)
5	O	Cassette presence (0—cassette, 1—no cassette)
6	I	Read/Write (0—read, 1—write)
7	O	File protect (0—tab present, 1—tab removed)
8	—	+5v motor power
9	—	Power ground
10	—	Chassis ground
11	I	Direction (0—forward, 1—rewind)
12	I	Speed (0—fast, 1—slow)
13	O	Data output (0—space, 1—mark)
14	O	Clear leader (0—clear leader, 1—off clear leader)
15	I	Motion (0—go, 1—stop)
16	—	+5v logic power

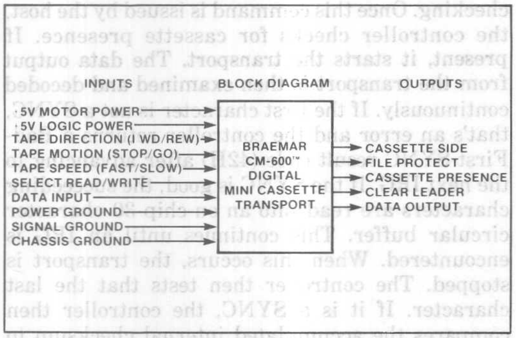

Figure 3. Braemar CM-600™ Block Diagram

Figure 4 illustrates the encoding of the character 3AH assuming the previous data ended with the data line high. (The least significant bit is sent first.) Notice that there is always a "clocking" transition at the beginning of each cell. Decoding is simply a matter of triggering on this "clocking" transition, waiting 3/4 of a bit cell time, and determining whether a mid-cell transition has occurred. Cells with no mid-cell transitions are data 0's; cells with transitions are data 1's. This encoding technique has all the benefits of Manchester encoding with the added advantage that the encoded data may be "decoded by eyeball:" long cells are always 0's, short cells are always 1's.

Besides the encoding scheme, the data format is also up to the user. This controller uses a variable byte length, checksum protected block format. Every block starts and ends with a SYNC character

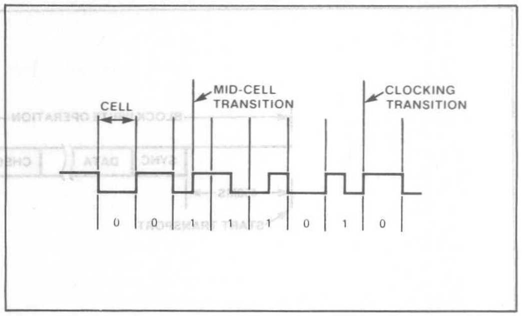

Figure 4. Modified Phase Encoding of Character 3A Hex

(AAH), and the character immediately preceeding the last SYNC is the checksum. The checksum is capable of catching 2 bit errors. The number of data characters within a block is limited to 64K bytes. Blocks are separated by an Inter-Record Gap (IRG). The IRG is of such a length that the transport can stop and start within an IRG, as illustrated in the data block timing, figure 5. Braemar specifies a maximum start or stop time of 150ms for the transport, thus the controller uses 450ms for the IRG. This gives plenty of margin for controlling the transport and also for detecting IRGs while skipping blocks.

THE UPI-41A CONTROLLER

The goal of the UPI software design for this application was to make the UPI-41A microcomputer into an intelligent cassette control processor. The host processor (8086, 8088, 8085A, etc.) simply issues a high-level command such as READ-a-block or WRITE-a-block. The 8741A accepts the command, performs the requested operation, and returns to the host system a result code telling the outcome of the operation, eg. Good-Completion, Sync Error, etc. Table 2 shows the command and result code repertoire. The 8741A completely manages all the data transfers for reading and writing.

As an example, consider the WRITE-a-block command. When this command is issued, the UPI-41A expects a 16-bit number from the host telling how many data bytes to write (up to 64K bytes per block). Once this number is supplied in the form of two bytes, the host is free to perform other tasks; a bit in the UPI's STATUS register or an interrupt output will notify the host when a data transfer is required. The 8741A then checks the transport's status to be sure that a cassette is present and not file protected. If either is false, a result code is

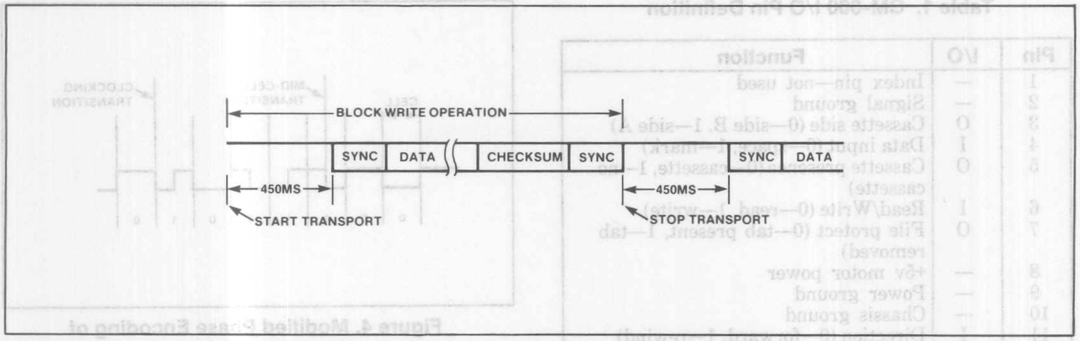

Figure 5. IRG/Block Timing Diagram (not to scale)

Table 2. Controller Command/Result Code Set

Command	Result
Read (01H)	Good-Completion (00H) Buffer Overrun Error (41H) Bad Synch1 Error (42H) Bad Synch2 Error (43H) Checksum Error (44H) Command Error (45H) End of Tape Error (46H)
Rewind (04H)	Good-Completion (00H)
Skip (03H)	Good-Completion (00H) End of Tape Error (47H) Beginning of Tape Error (48H)
Write (02H)	Good-Completion (00H) Buffer Underrun Error (81H) Command Error (82H) End of Tape Error (83H)

returned to the host; otherwise the transport is started. After the peripheral controller checks to make sure that the tape is off the clear leader and past the hole in the tape, it writes a 450ms IRG, a SYNC character, the block of data, the checksum, and the final SYNC character. (The tape has a clear leader at both ends and a small hole 6 inches from the end of each leader.) The data transfers from the host to the UPI-41A slave microcomputer are double buffered. The controller requests only the desired number of data bytes by keeping track of the count internally.

If nothing unusual happened, such as finding clear leader while writing, it returns a Good-Completion result code to the host. If clear leader was encountered, the transport is stopped immediately and an End-of-Tape result code is returned to the host. Another possible error would be if the host is late in supplying data. If this occurs, the controller writes an IRG, stops the drive, and returns the appropriate Data-Underrun result code.

The READ-a-block command also provides error checking. Once this command is issued by the host, the controller checks for cassette presence. If present, it starts the transport. The data output from the transport is then examined and decoded continuously. If the first character is not a SYNC, that's an error and the controller returns a Bad-First-SYNC result code (42H) after advancing to the next IRG. If the SYNC is good, the succeeding characters are read into an on-chip 30 character circular buffer. This continues until an IRG is encountered. When this occurs, the transport is stopped. The controller then tests that the last character. If it is a SYNC, the controller then compares the accumulated internal checksum to the block's checksum, the second to the last character of the block. If they match, a Good-Completion result code (00H) is returned to the host. If either test is bad, the appropriate error result code is returned. The READ command also checks for the End-of-Tape (EOT) clear leader and returns the appropriate error result code if it is found before the read operation is complete.

The 30 character circular buffer allows the host up to 30 character times of response time before the host must collect the data. All data transfers take place thru the UPI-41A Data Bus Buffer Output register (DBBOUT). The controller continually monitors the status of this register and moves characters from the circular buffer to the register whenever it is empty.

The SKIP-n-blocks command allows the host to skip the transport forward or backward up to 127 blocks. Once the command is issued, the controller expects one data byte specifying the number of

blocks to skip. The most significant bit of this byte selects the direction of the skip (0=forward, 1=reverse). SKIP is a dual-speed operation in the forward direction. If the number of blocks to skip is greater than 8, the controller uses fast-forward (5 IPS) until it is within 8 blocks of the desired location. Once within 8 blocks, the controller switches to the normal read speed (3 IPS) to allow accurate placement of the tape. The reverse skip uses only the rewind speed (15 IPS). Like the READ and WRITE commands, SKIP also checks for EOT and beginning-of-tape (BOT) depending upon the tape's direction. An error result code is returned if either is encountered before the number of blocks skipped is complete.

The REWIND command simply rewinds the tape to the BOT clear leader. The ABORT command allows the termination of any operation in progress, except a REWIND. All commands, including ABORT, always leave the tape positioned on an IRG.

THE HARDWARE INTERFACE

There's hardly any hardware design effort required for the controller and transport interface in figure 6. Since the CM-600 is TTL compatible, it connects directly to the I/O ports of the UPI controller. If the two are separated (i.e. on different PC cards), it is recommended that TTL buffers be provided.) The only external circuitry needed is an LED driver for the DRIVE ACTIVE status indicator.

The 8741A-to-host interface is equally straightforward. It has a standard asynchronous peripheral interface: 8 data lines (D_0-D_7), read (RD), write (WR), register select (AO), and chip select (CS). Thus it connects directly to an 8086, 8088, 8085A, 8080, or 8048 bus structure. Two interrupt outputs are provided for data transfer requests if the particular system is interrupt-driven. DMA transfer capability is also available. The clock input can be driven from a crystal directly or with the system clock (6MHz max). The UPI-41A clock may be asynchronous with respect to other clocks within the system.

This application was developed on an Intel iSBC 80/30 single board computer. The iSBC 80/30 is controlled by an 8085A microprocessor, contains 16K bytes of dual-ported dynamic RAM and up to 8K bytes of either EPROM or ROM. Its I/O complement consists of an 8255A Programmable Parallel Interface, an 8251A Programmable Communica-

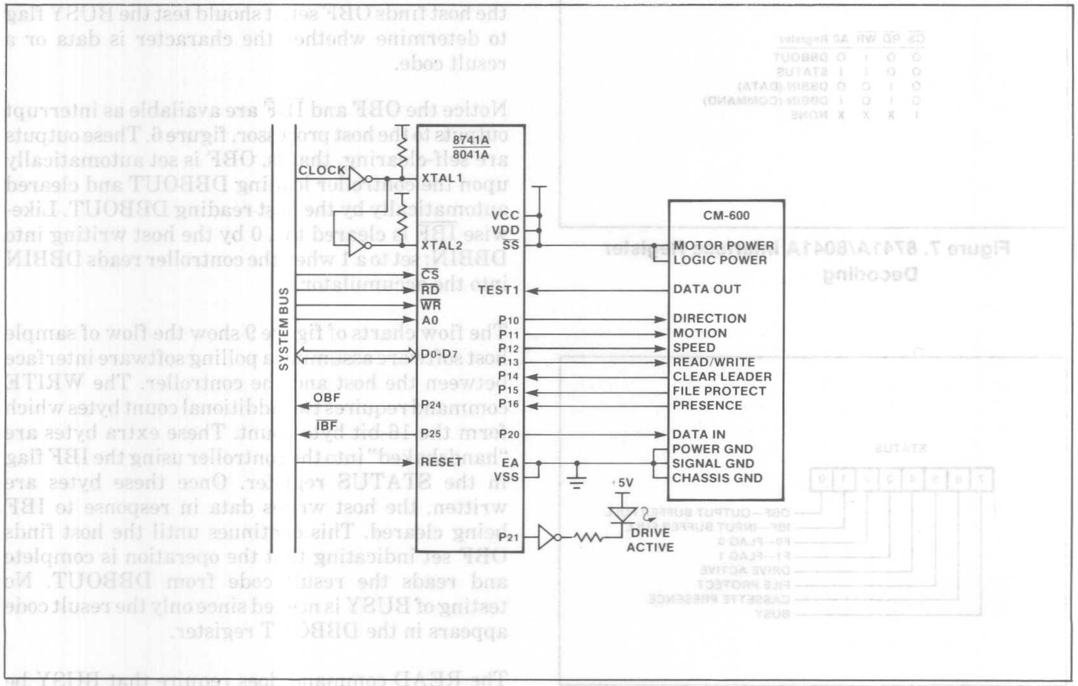

Figure 6. Controller/Transport System Schematic

AFN-01342A

tions Interface, an 8253 Programmable Interval Timer, and an 8259A Programmable Interrupt Controller. The iSBC 80/30 is especially convenient for UPI development since it contains an uncommitted socket dedicated to either an 8041A or 8741A, complete with buffering for its I/O ports. The iSBC 80/30 to 8741A interface is reflected in figure 8. (Optionally, an iSBC 569 Digital Controller board could be used. The iSBC 569 board contains three uncommitted UPI sockets with an interface similar to that in figure 8.)

Looking at the host-to-controller interface, the host sees the 8741A as three registers in the host's I/O address space: the data register, the command register, and the status register. The decoding of these registers is shown in figure 7. All data and commands for the controller are written into the Data Bus Buffer Input register (DBBIN). The state of the register select input, AO, determines whether a command or data is written. (Writes with AO set to 1 are commands by convention.) All data and results from the controller are read by the host from the Data Bus Buffer Output register (DBBOUT).

$\overline{CS}$	$\overline{RD}$	$\overline{WR}$	A0	Register
O	O	I	O	DBBOUT
O	O	I	I	STATUS
O	I	O	O	DBBIN (DATA)
O	I	O	I	DBBIN (COMMAND)
I	X	X	X	NONE

Figure 7. 8741A/8041A Interface Register Decoding

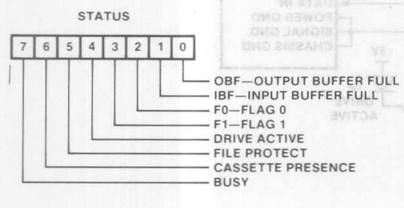

Figure 8. Status Register Bit Definition

The Status register contains flags which give the host the status of various operations within the controller. Its format is given in figure 8. The Input Buffer Full (IBF) and Output Buffer Full (OBF) flags show the Status of the DBBIN and DBBOUT registers respectively. IBF indicates when the DBBIN register contains data written by the host. The host may write to DBBIN only when IBF is 0. Likewise, the host may read DBBOUT only when OBF is set to a 1. These bits are handled automatically by the UPI-41A internal hardware. FLAG 0 (F_0) and FLAG 1 (F_1) are general purpose flags used internally by the controller which have no meaning externally.

The remaining four bits are user-definable. For this application they are DRIVE ACTIVE, FILE PROTECT, CASSETTE PRESENCE, and BUSY flags. The FILE PROTECT and CASSETTE PRESENCE flags reflect the state of the corresponding I/O lines from the transport. DRIVE ACTIVE is set whenever the transport motor is on and the controller is performing an operation. The BUSY flag indicates whether the contents of the DBBOUT register is data or a result code. The BUSY flag is set whenever a command is issued by the host and accepted by the controller. As long as BUSY is set, any character found in DBBOUT is a result code. Thus whenever the host finds OBF set, it should test the BUSY flag to determine whether the character is data or a result code.

Notice the OBF and $\overline{IBF}$ are available as interrupt outputs to the host processor, figure 6. These outputs are self-clearing, that is, OBF is set automatically upon the controller loading DBBOUT and cleared automatically by the host reading DBBOUT. Likewise $\overline{IBF}$ is cleared to a 0 by the host writing into DBBIN: set to a 1 when the controller reads DBBIN into the accumulator.

The flow charts of figure 9 show the flow of sample host software assuming a polling software interface between the host and the controller. The WRITE command requires two additional count bytes which form the 16-bit byte count. These extra bytes are "handshaked" into the controller using the IBF flag in the STATUS register. Once these bytes are written, the host writes data in response to IBF being cleared. This continues until the host finds OBF set indicating that the operation is complete and reads the result code from DBBOUT. No testing of BUSY is needed since only the result code appears in the DBBOUT register.

The READ command does require that BUSY be tested. Once the READ command is written into the

controller, the host must test BUSY whenever OBF is set to determine whether the contents of DBBOUT is data from the tape or the result code.

THE CONTROLLER SOFTWARE

The UPI-41A software to control the cassette can be divided up into various commands such as WRITE, READ and ABORT. In a previous version of this application note (May 1980), software was described that implemented these commands. This code however did not adequately compensate for speed variations of the motor during record and playback nor for data distortion caused by the magnetic media. Since then, new code has been written to include these effects. This revised software is now available through the INTEL User's Library, INSITE. For more information on this software or INSITE, contact your local INTEL Sales Office.

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8041A/8641A/8741A
UNIVERSAL PERIPHERAL INTERFACE 8-BIT MICROCOMPUTER

- 8-Bit CPU plus ROM, RAM, I/O, Timer and Clock in a Single Package
- One 8-Bit Status and Two Data Registers for Asynchronous Slave-to-Master Interface
- DMA, Interrupt, or Polled Operation Supported
- 1024 × 8 ROM/EPROM, 64 × 8 RAM, 8-Bit Timer/Counter, 18 Programmable I/O Pins
- Fully Compatible with MCS-48™, MCS-80™, MCS-85™, and MCS-86™ Microprocessor Families
- Interchangeable ROM and EPROM Versions
- 3.6 MHz 8741A-8 Available
- Expandable I/O
- RAM Power-Down Capability
- Over 90 Instructions: 70% Single Byte
- Single 5V Supply

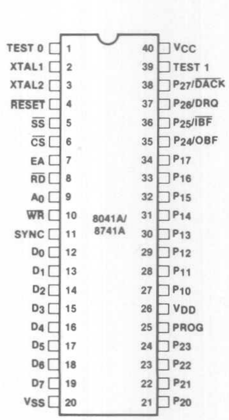
The Intel® 8041A/8741A is a general purpose, programmable interface device designed for use with a variety of 8-bit microprocessor systems. It contains a low cost microcomputer with program memory, data memory, 8-bit CPU, I/O ports, timer/counter, and clock in a single 40-pin package. Interface registers are included to enable the UPI device to function as a peripheral controller in MCS-48™, MCS-80™, MCS-85™, MCS-86™, and other 8-bit systems.

The UPI-41A™ has 1K words of program memory and 64 words of data memory on-chip. To allow full user flexibility the program memory is available as ROM in the 8041A version or as UV-erasable EPROM in the 8741A version. The 8741A and the 8041A are fully pin compatible for easy transition from prototype to production level designs. The 8641A is a one-time programmable (at the factory) 8741A which can be ordered as the first 25 pieces of a new 8041A order. The substitution of 8641A's for 8041A's allows for very fast turnaround for initial code verification and evaluation results.

The device has two 8-bit, TTL compatible I/O ports and two test inputs. Individual port lines can function as either inputs or outputs under software control. I/O can be expanded with the 8243 device which is directly compatible and has 16 I/O lines. An 8-bit programmable timer/counter is included in the UPI device for generating timing sequences or counting external inputs. Additional UPI features include: single 5V supply, low power standby mode (in the 8041A), single-step mode for debug (in the 8741A), and dual working register banks.

Because it's a complete microcomputer, the UPI provides more flexibility for the designer than conventional LSI interface devices. It is designed to be an efficient controller as well as an arithmetic processor. Applications include keyboard scanning, printer control, display multiplexing and similar functions which involve interfacing peripheral devices to microprocessor systems.

PIN CONFIGURATION



BLOCK DIAGRAM

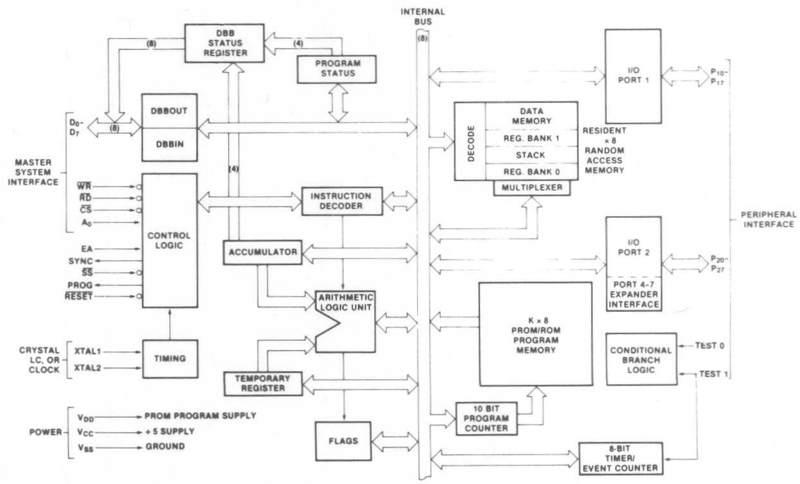


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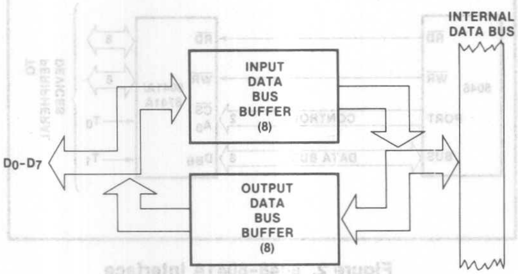
Table 1. Pin Description

Signal	Description
D_0–D_7 (BUS)	Three-state, bidirectional DATA BUS BUFFER lines used to interface the UPI-41A to an 8-bit master system data bus.
P_{10}–P_{17}	8-bit, PORT 1 quasi-bidirectional I/O lines.
P_{20}–P_{27}	8-bit, PORT 2 quasi-bidirectional I/O lines. The lower 4 bits (P_{20}–P_{23}) interface directly to the 8243 I/O expander device and contain address and data information during PORT 4–7 access. The upper 4 bits (P_{24}–P_{27}) can be programmed to provide Interrupt Request and DMA Handshake capability. Software control can configure P_{24} as OBF (Output Buffer Full), P_{25} as $\overline{IBF}$ (Input Buffer Full), P_{26} as DRQ (DMA Request), and P_{27} as $\overline{DACK}$ (DMA ACKnowledge).
$\overline{WR}$	I/O write input which enables the master CPU to write data and command words to the UPI-41A INPUT DATA BUS BUFFER.
$\overline{RD}$	I/O read input which enables the master CPU to read data and status words from the OUTPUT DATA BUS BUFFER or status register.
$\overline{CS}$	Chip select input used to select one UPI-41A out of several connected to a common data bus.
A_0	Address input used by the master processor to indicate whether byte transfer is data or command. During a write operation flag F_1 is set to the status of the A_0 input.
TEST 0, TEST 1	Input pins which can be directly tested using conditional branch instructions. T_1 also functions as the event timer input (under software control). T_0 is used during PROM programming and verification in the 8741A.
XTAL1, XTAL2	Inputs for a crystal, LC or an external timing signal to determine the internal oscillator frequency.
SYNC	Output signal which occurs once per UPI-41A instruction cycle. SYNC can be used as a strobe for external circuitry; it is also used to synchronize single step operation.
EA	External access input which allows emulation, testing and PROM/ROM verification.
PROG	Multifunction pin used as the program pulse input during PROM programming. During I/O expander access the PROG pin acts as an address/data strobe to the 8243.
$\overline{RESET}$	Input used to reset status flip-flops and to set the program counter to zero. $\overline{RESET}$ is also used during PROM programming and verification. $\overline{RESET}$ should be held low for a minimum of 8 instruction cycles after power-up.
$\overline{SS}$	Single step input used in the 8741A in conjunction with the SYNC output to step the program through each instruction.
V_{CC}	+5V main power supply pin.
V_{DD}	+5V during normal operation. +25V during programming operation. Low power standby pin in ROM version.
V_{SS}	Circuit ground potential.

UPI-41A™ FEATURES AND ENHANCEMENTS

1. Two Data Bus Buffers, one for input and one for output. This allows a much cleaner Master/Slave protocol.



2. 8 Bits of Status

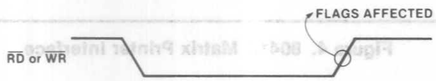
ST7	ST6	ST5	ST4	F1	F0	IBF	OBF
D7	D6	D5	D4	D3	D2	D1	D0

ST_4-ST_7 are user definable status bits. These bits are defined by the "MOV STS, A" single byte, single cycle instruction. Bits 4-7 of the accumulator are moved to bits 4-7 of the status register. Bits 0-3 of the status register are not affected.

MOV STS, A Op Code: 90H

D7							D0
1	0	0	1	0	0	0	0

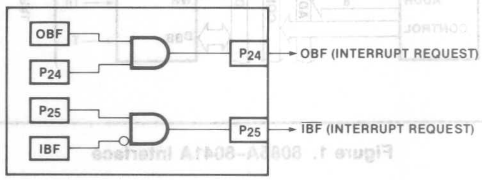
3. $\overline{RD}$ and $\overline{WR}$ are edge triggered. IBF, OBF, F_1 and INT change internally after the trailing edge of $\overline{RD}$ or $\overline{WR}$.



4. P_{24} and P_{25} are port pins or Buffer Flag pins which can be used to interrupt a master processor. These pins default to port pins on Reset.

If the "EN FLAGS" instruction has been executed, P_{24} becomes the OBF (Output Buffer Full) pin. A "1" written to P_{24} enables the OBF pin (the pin outputs the OBF Status Bit). A "0" written to P_{24} disables the OBF pin (the pin remains low). This pin can be used to indicate that valid data is available from the UPI-41A (in Output Data Bus Buffer).

If "EN FLAGS" has been executed, P_{25} becomes the $\overline{IBF}$ (Input Buffer Full) pin. A "1" written to P_{25} enables the $\overline{IBF}$ pin (the pin outputs the inverse of the IBF Status Bit). A "0" written to P_{25} disables the $\overline{IBF}$ pin (the pin remains low). This pin can be used to indicate that the UPI-41A is ready for data.



DATA BUS BUFFER INTERRUPT CAPABILITY

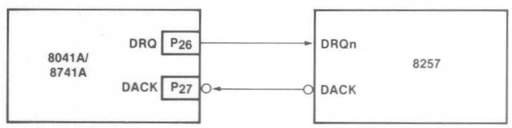
EN FLAGS Op Code: 0F5H

D7							D0
1	1	1	1	0	1	0	1

5. P_{26} and P_{27} are port pins or DMA handshake pins for use with a DMA controller. These pins default to port pins on Reset.

If the "EN DMA" instruction has been executed, P_{26} becomes the DRQ (DMA ReQuest) pin. A "1" written to P_{26} causes a DMA request (DRQ is activated). DRQ is deactivated by DACK·RD, DACK·WR, or execution of the "EN DMA" instruction.

If "EN DMA" has been executed, P_{27} becomes the $\overline{DACK}$ (DMA ACKnowledge) pin. This pin acts as a chip select input for the Data Bus Buffer registers during DMA transfers.



DMA HANDSHAKE CAPABILITY

EN DMA Op Code: 0E5H

D1							D0
1	1	1	0	0	1	0	1

AFN-00188B

APPLICATIONS

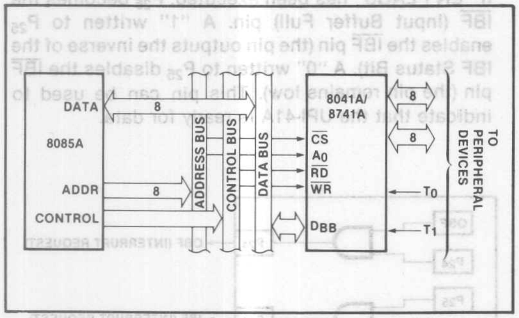


Figure 1. 8085A-8041A Interface

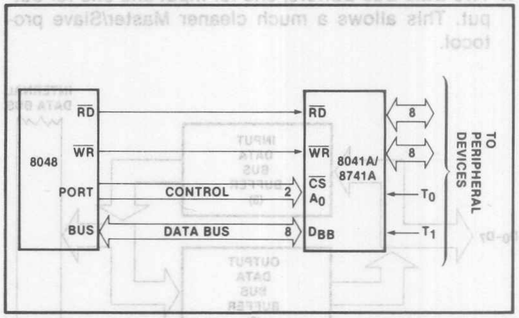


Figure 2. 8048-8041A Interface

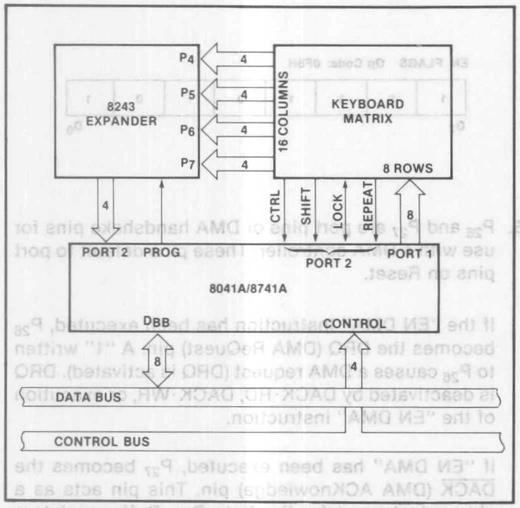


Figure 3. 8041A-8243 Keyboad Scanner

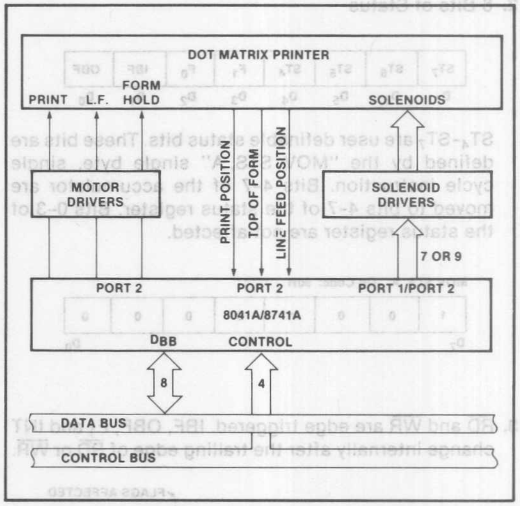


Figure 4. 8041A Matrix Printer Interface

PROGRAMMING, VERIFYING, AND ERASING THE 8741A EPROM

Programming Verification

In brief, the programming process consists of: activating the program mode, applying an address, latching the address, applying data, and applying a programming pulse. Each word is programmed completely before moving on to the next and is followed by a verification step. The following is a list of the pins used for programming and a description of their functions:

Pin	Function
XTAL 1	Clock Input (1 to 6MHz)
$\overline{\text{Reset}}$	Initialization and Address Latching
Test 0	Selection of Program or Verify Mode
EA	Activation of Program/Verify Modes
BUS	Address and Data Input Data Output During Verify
P20-1	Address Input
V_{DD}	Programming Power Supply
PROG	Program Pulse Input

WARNING:

An attempt to program a missocketed 8741A will result in severe damage to the part. An indication of a properly socketed part is the appearance of the SYNC clock output. The lack of this clock may be used to disable the programmer.

The Program/Verify sequence is:

1. A_0 = 0V, $\overline{CS}$ = 5V, EA = 5V, $\overline{RESET}$ = 0V, TEST0 = 5V, V_{DD} = 5V, clock applied or internal oscillator operating, BUS and PROG floating.
2. Insert 8741A in programming socket
3. TEST 0 = 0v (select program mode)
4. EA = 23V (activate program mode)
5. Address applied to BUS and P20-1
6. $\overline{RESET}$ = 5v (latch address)
7. Data applied to BUS
8. V_{DD} = 25v (programming power)
9. PROG = 0v followed by one 50ms pulse to 23V
10. V_{DD} = 5v
11. TEST 0 = 5v (verify mode)
12. Read and verify data on BUS
13. TEST 0 = 0v
14. $\overline{RESET}$ = 0v and repeat from step 5
15. Programmer should be at conditions of step 1 when 8741A is removed from socket.

8741A Erasure Characteristics

The erasure characteristics of the 8741A are such that erasure begins to occur when exposed to light with wavelengths shorter than approximately 4000 Angstroms (Å). It should be noted that sunlight and certain types of fluorescent lamps have wavelengths in the 3000-4000Å range. Data show that constant exposure to room level fluorescent lighting could erase the typical 8741A in approximately 3 years while it would take approximately one week to cause erasure when exposed to direct sunlight. If the 8741A is to be exposed to these types of lighting conditions for extended periods of time, opaque labels are available from Intel which should be placed over the 8741A window to prevent unintentional erasure.

The recommended erasure procedure for the 8741A is exposure to shortwave ultraviolet light which has a wavelength of 2537Å. The integrated dose (i.e., UV intensity × exposure time) for erasure should be a minimum of 15 w-sec/cm^2. The erasure time with this dosage is approximately 15 to 20 minutes using an ultraviolet lamp with a 12,000 $\mu W/cm^2$ power rating. The 8741A should be placed within one inch of the lamp tubes during erasure. Some lamps have a filter on their tubes which should be removed before erasure.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias . . . . 0°C to 70°C
Storage Temperature . . . . – 65°C to + 150°C
Voltage on Any Pin With Respect
to Ground . . . . 0.5V to + 7V
Power Dissipation . . . . 1.5 Watt

*COMMENT: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. AND OPERATING CHARACTERISTICS

$T_A = 0°C$ to $70°C$, $V_{SS} = 0V$, 8041A: $V_{CC} = V_{DD} = +5V \pm 10\%$, 8741A: $V_{CC} = V_{DD} = +5V \pm 5\%$

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
V_{IL}	Input Low Voltage (Except XTAL1, XTAL2, $\overline{RESET}$)	– 0.5	0.8	V	
V_{IL1}	Input Low Voltage (XTAL1, XTAL2, $\overline{RESET}$)	– 0.5	0.6	V	
V_{IH}	Input High Voltage (Except XTAL1, XTAL2, $\overline{RESET}$)	2.2	V_{CC}		
V_{IH1}	Input High Voltage (XTAL1, XTAL2, $\overline{RESET}$)	3.8	V_{CC}	V	
V_{OL}	Output Low Voltage (D_0-D_7)		0.45	V	$I_{OL} = 2.0$ mA
V_{OL1}	Output Low Voltage ($P_{10}P_{17}$, $P_{20}P_{27}$, Sync)		0.45	V	$I_{OL} = 1.6$ mA
V_{OL2}	Output Low Voltage (Prog)		0.45	V	$I_{OL} = 1.0$ mA
V_{OH}	Output High Voltage (D_0–D_7)	2.4		V	$I_{OH} = -400\ \mu A$
V_{OH1}	Output High Voltage (All Other Outputs)	2.4		V	$I_{OH} = -50\ \mu A$
I_{IL}	Input Leakage Current (T_0, T_1, $\overline{RD}$, $\overline{WR}$, $\overline{CS}$, A_0, EA)		± 10	μA	$V_{SS} \leq V_{IN} \leq V_{CC}$
I_{OZ}	Output Leakage Current (D_0–D_7, High Z State)		± 10	μA	$V_{SS} + 0.45 \leq V_{IN} \leq V_{CC}$
I_{LI}	Low Input Load Current ($P_{10}P_{17}$, $P_{20}P_{27}$)		0.5	mA	$V_{IL} = 0.8V$
I_{LI1}	Low Input Load Current ($\overline{RESET}$, $\overline{SS}$)		0.2	mA	$V_{IL} = 0.8V$
I_{DD}	V_{DD} Supply Current		15	mA	Typical = 5 mA
$I_{CC} + I_{DD}$	Total Supply Current		125	mA	Typical = 60 mA

A.C. CHARACTERISTICS

$T_A = 0°C$ to $70°C$, $V_{SS} = 0V$, 8041A: $V_{CC} = V_{DD} = +5V \pm 10\%$, 8741A: $V_{CC} = V_{DD} = +5V \pm 5\%$

DBB READ

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AR}	$\overline{CS}$, A_0 Setup to $\overline{RD}\downarrow$	0		ns	
t_{RA}	$\overline{CS}$, A_0 Hold After $\overline{RD}\uparrow$	0		ns	
t_{RR}	$\overline{RD}$ Pulse Width	250		ns	
t_{AD}	$\overline{CS}$, A_0 to Data Out Delay		225	ns	$C_L = 150$ pF
t_{RD}	$\overline{RD}\downarrow$ to Data Out Delay		225	ns	$C_L = 150$ pF
t_{DF}	$\overline{RD}\uparrow$ to Data Float Delay		100	ns	
t_{CY}	Cycle Time (Except 8741A-8)	2.5	15	μs	6.0 MHz XTAL
t_{CY}	Cycle Time (8741A-8)	4.17	15	μs	3.6 MHz XTAL

DBB WRITE

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	$\overline{CS}$, A_0 Setup to $\overline{WR}\downarrow$	0		ns	
t_{WA}	$\overline{CS}$, A_0 Hold After $\overline{WR}\uparrow$	0		ns	
t_{WW}	$\overline{WR}$ Pulse Width	250		ns	
t_{DW}	Data Setup to $\overline{WR}\uparrow$	150		ns	
t_{WD}	Data Hold After $\overline{WR}\uparrow$	0		ns	

A.C. TIMING SPECIFICATION FOR PROGRAMMING

$T_A = 25°C \pm 5°C, V_{CC} = 5V \pm 5\%, V_{DD} = 25V \pm 1V$

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	Address Setup Time to $\overline{RESET}$ ↑	4tcy			
t_{WA}	Address Hold Time After $\overline{RESET}$ ↑	4tcy			
t_{DW}	Data in Setup Time to PROG ↑	4tcy			
t_{WD}	Data in Hold Time After PROG ↓	4tcy			
t_{PH}	$\overline{RESET}$ Hold Time to Verify	4tcy			
t_{VDDW}	V_{DD} Setup Time to PROG ↑	4tcy			
t_{VDDH}	V_{DD} Hold Time After PROG ↓	0			
t_{PW}	Program Pulse Width	50	60	mS	
t_{TW}	Test 0 Setup Time for Program Mode	4tcy			
t_{WT}	Test 0 Hold Time After Program Mode	4tcy			
t_{DO}	Test 0 to Data Out Delay		4tcy		
t_{WW}	$\overline{RESET}$ Pulse Width to Latch Address	4tcy			
t_r, t_f	V_{DD} and PROG Rise and Fall Times	0.5	2.0	μs	
t_{CY}	CPU Operation Cycle Time	5.0		μs	
t_{RE}	$\overline{RESET}$ Setup Time Before EA ↑.	4tcy			

Note: If TEST 0 is high, t_{DO} can be triggered by $\overline{RESET}$ ↑.

D.C. SPECIFICATION FOR PROGRAMMING

$T_A = 25°C \pm 5°C, V_{CC} = 5V \pm 5\%, V_{DD} = 25V \pm 1V$

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
V_{DOH}	V_{DD} Program Voltage High Level	24.0	26.0	V	
V_{DDL}	V_{DD} Voltage Low Level	4.75	5.25	V	
V_{PH}	PROG Program Voltage High Level	21.5	24.5	V	
V_{PL}	PROG Voltage Low Level		0.2	V	
V_{EAH}	EA Program or Verify Voltage High Level	21.5	24.5	V	
V_{EAL}	EA Voltage Low Level		5.25	V	
I_{DD}	V_{DD} High Voltage Supply Current		30.0	mA	
I_{PROG}	PROG High Voltage Supply Current		16.0	mA	
I_{EA}	EA High Voltage Supply Current		1.0	mA	

A.C. CHARACTERISTICS—PORT 2

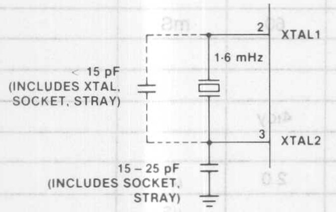
$T_A = 0°C$ to $70°C$, 8041A: $V_{CC} = +5V \pm 10\%$, 8741A: $V_{CC} = +5V \pm 5\%$

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{CP}	Port Control Setup Before Falling Edge of PROG	110		ns	
t_{PC}	Port Control Hold After Falling Edge of PROG	100		ns	
t_{PR}	PROG to Time P2 Input Must Be Valid		810	ns	
t_{PF}	Input Data Hold Time	0	150	ns	
t_{DP}	Output Data Setup Time	250		ns	
t_{PD}	Output Data Hold Time	65		ns	
t_{PP}	PROG Pulse Width	1200		ns	

A.C. CHARACTERISTICS—DMA

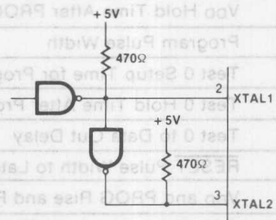
Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{ACC}	$\overline{DACK}$ to $\overline{WR}$ or $\overline{RD}$	0		ns	
t_{CAC}	$\overline{RD}$ or $\overline{WR}$ to $\overline{DACK}$	0		ns	
t_{ACD}	$\overline{DACK}$ to Data Valid		225	ns	$C_L = 150$ pF
t_{CRQ}	$\overline{RD}$ or $\overline{WR}$ to DRQ Cleared		200	ns	

CRYSTAL OSCILLATOR MODE



CRYSTAL SERIES RESISTANCE SHOULD BE <75Ω AT 6 MHz; <180Ω AT 3.6 MHz.

DRIVING FROM EXTERNAL SOURCE



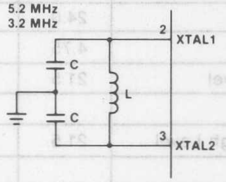
BOTH XTAL1 AND XTAL2 SHOULD BE DRIVEN.
RESISTORS TO V_{CC} ARE NEEDED TO ENSURE $V_{IH} = 3.8V$ IF TTL CIRCUITRY IS USED.

LC OSCILLATOR MODE

L	C	NOMINAL f
45 μH	20 pF	5.2 MHz
120 μH	20 pF	3.2 MHz

$$f = \frac{1}{2\pi\sqrt{LC'}}$$

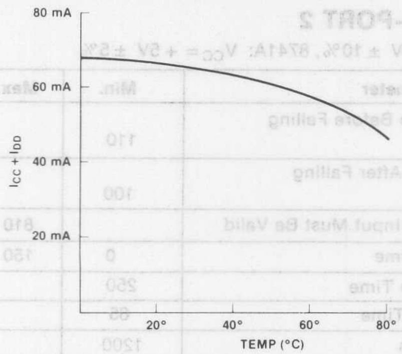
$$C' = \frac{C + 3C_{PP}}{2}$$



$C_{PP} \approx 5 - 10$ pF PIN-TO-PIN CAPACITANCE

EACH C SHOULD BE APPROXIMATELY 20 pF, INCLUDING STRAY CAPACITANCE.

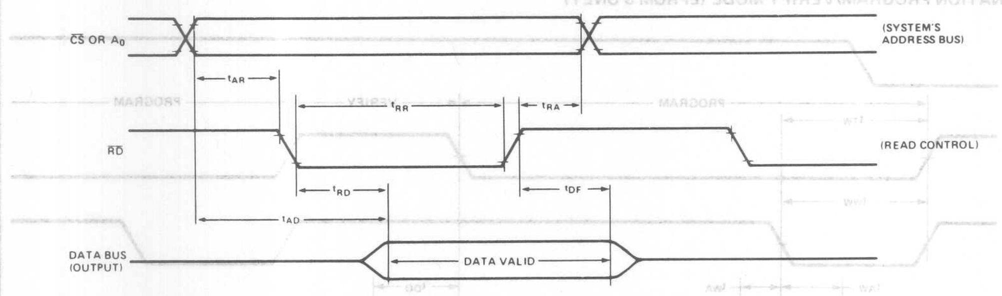
TYPICAL 8041/8741A CURRENT



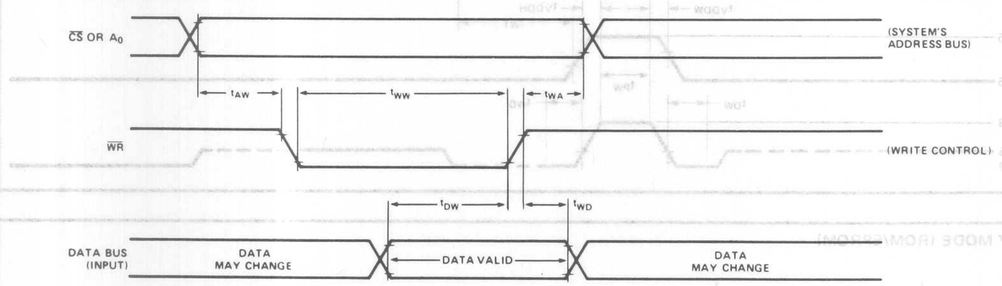
AFN-00188B

WAVEFORMS

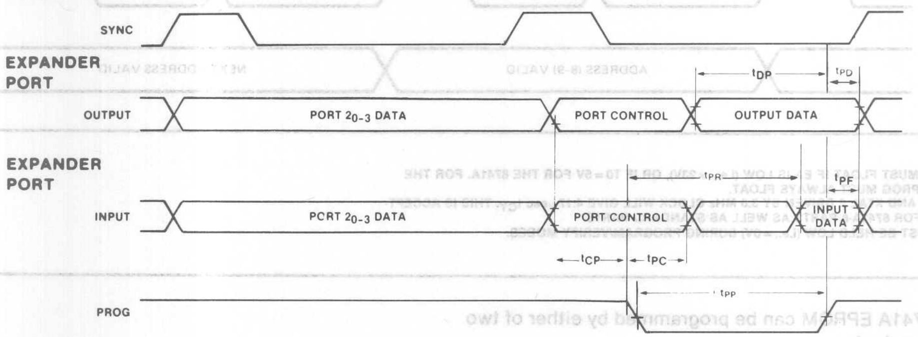
READ OPERATION—DATA BUS BUFFER REGISTER.



WRITE OPERATION—DATA BUS BUFFER REGISTER.

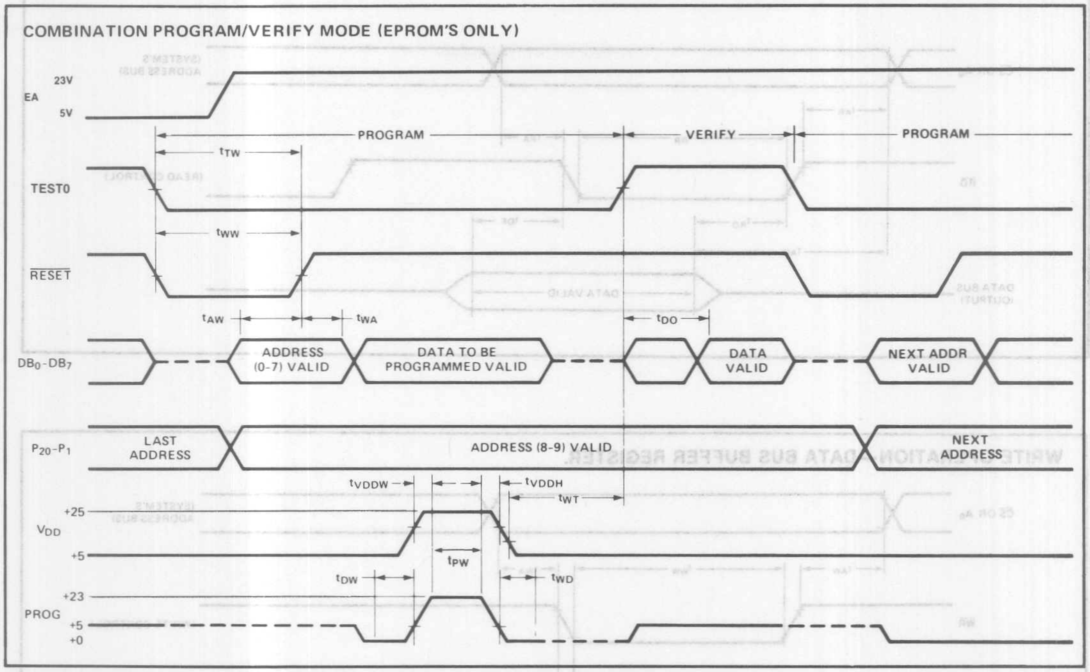


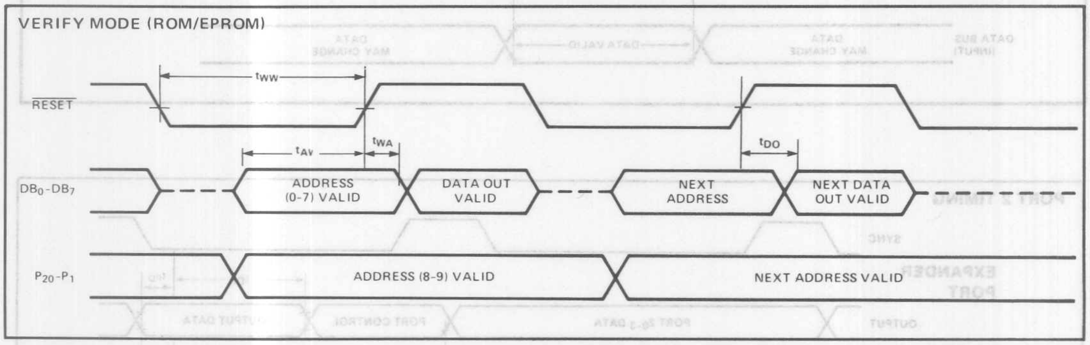
PORT 2 TIMING



AFN-00188B

WAVEFORMS FOR PROGRAMMING



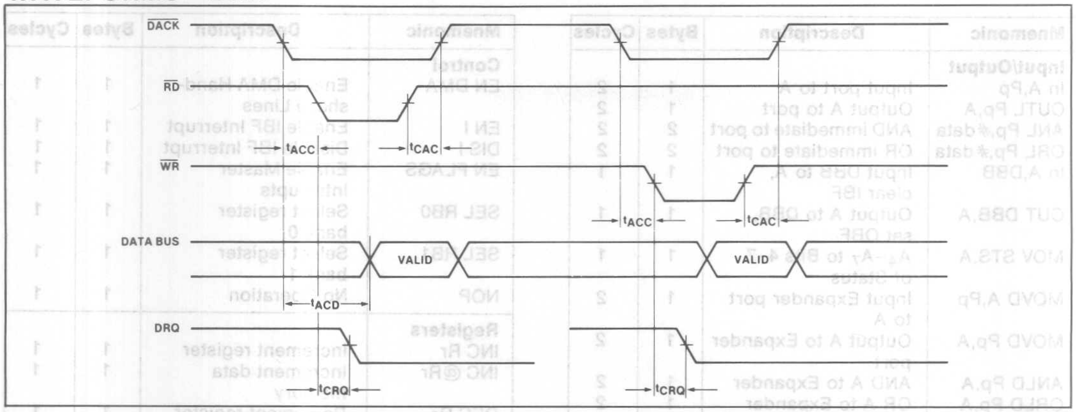


NOTES:
1. PROG MUST FLOAT IF EA IS LOW (i.e., ≠23V), OR IF T0 = 5V FOR THE 8741A. FOR THE 8041A PROG MUST ALWAYS FLOAT.
2. XTAL1 AND XTAL 2 DRIVEN BY 3.6 MHz CLOCK WILL GIVE 4.17 μsec t_{CY}. THIS IS ACCEPTABLE FOR 8741A-8 PARTS AS WELL AS STANDARD PARTS.
3. AO MUST BE HELD LOW (i.e., = 0V) DURING PROGRAM/VERIFY MODES.

The 8741A EPROM can be programmed by either of two Intel products:

1. PROMPT-48 Microcomputer Design Aid, or
2. Universal PROM Programmer (UPP series) peripheral of the Intellec® Development System with a UPP-848 Personality Card.

WAVEFORMS—DMA



INPUT AND OUTPUT WAVEFORMS FOR A.C. TESTS

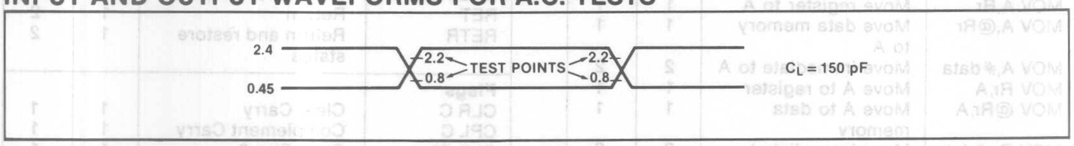


Table 2. UPI™ Instruction Set

Mnemonic	Description	Bytes	Cycles
Accumulator			
ADD A,Rr	Add register to A	1	1
ADD A,@Rr	Add data memory to A	1	1
ADD A,#data	Add immediate to A	2	2
ADDC A,Rr	Add register to A with carry	1	1
ADDC A,@Rr	Add data memory to A with carry	1	1
ADDC A, #data	Add immed. to A with carry	2	2
ANL A,Rr	AND register to A	1	1
ANL A,@Rr	AND data memory to A	1	1
ANL A,#data	AND immediate to A	2	2
ORL A,Rr	OR register to A	1	1
ORL A,@Rr	OR data memory to A	1	1
ORL A,#data	OR immediate to A	2	2
XRL A,Rr	Exclusive OR register to A	1	1
XRL A,@Rr	Exclusive OR data memory to A	1	1
XRL A,#data	Exclusive OR immediate to A	2	2
INC A	Increment A	1	1
DEC A	Decrement A	1	1
CLR A	Clear A	1	1
CPL A	Complement A	1	1
DA A	Decimal Adjust A	1	1
SWAP A	Swap nibbles of A	1	1
RL A	Rotate A left	1	1
RCL A	Rotate A left through carry	1	1
RR A	Rotate A right	1	1
RRC A	Rotate A right through carry	1	1

Table 2. UPI™ Instruction Set (Cont'd.)

Mnemonic	Description	Bytes	Cycles
Input/Output			
In A,Pp	Input port to A	1	2
OUTL Pp,A	Output A to port	1	2
ANL Pp,#data	AND immediate to port	2	2
ORL Pp,#data	OR immediate to port	2	2
In A,DBB	Input DBB to A, clear IBF	1	1
OUT DBB,A	Output A to DBB, set OBF	1	1
MOV STS,A	A_4–A_7 to Bits 4–7 of Status	1	1
MOVD A,Pp	Input Expander port to A	1	2
MOVD Pp,A	Output A to Expander port	1	2
ANLD Pp,A	AND A to Expander	1	2
ORLD Pp,A	OR A to Expander port	1	2
Data Moves			
MOV A,Rr	Move register to A	1	1
MOV A,@Rr	Move data memory to A	1	1
MOV A,#data	Move immediate to A	2	2
MOV Rr,A	Move A to register	1	1
MOV @Rr,A	Move A to data memory	1	1
MOV Rr,#data	Move immediate to register	2	2
MOV @Rr, #data	Move immediate to data memory	2	2
MOV A,PSW	Move PSW to A	1	1
MOV PSW,A	Move A to PSW	1	1
XCH A,Rr	Exchange A and register	1	1
XCH A,@Rr	Exchange A and data memory	1	1
XCHD A,@Rr	Exchange digit of A and register	1	1
MOVP A,@A	Move to A from current page	1	2
MOVP3, A,@A	Move to A from page 3	1	2
Timer/Counter			
MOV A,T	Read Timer/Counter	1	1
MOV T,A	Load Timer/Counter	1	1
STRT T	Start Timer	1	1
STRT CNT	Start Counter	1	1
STOP TCNT	Stop Timer/Counter	1	1
EN TCNTI	Enable Timer/Counter	1	1
DIS TCNTI	Disable Timer/ Counter Interrupt	1	1

Mnemonic	Description	Bytes	Cycles
Control			
EN DMA	Enable DMA Hand-shake Lines	1	1
EN I	Enable IBF Interrupt	1	1
DIS I	Disable IBF Interrupt	1	1
EN FLAGS	Enable Master Interrupts	1	1
SEL RB0	Select register bank 0	1	1
SEL RB1	Select register bank 1	1	1
NOP	No Operation	1	1
Registers			
INC Rr	Increment register	1	1
INC @Rr	Increment data memory	1	1
DEC Rr	Decrement register	1	1
Subroutine			
CALL addr	Jump to subroutine	2	2
RET	Return	1	2
RETR	Return and restore status	1	2
Flags			
CLR C	Clear Carry	1	1
CPL C	Complement Carry	1	1
CLR F0	Clear Flag 0	1	1
CPL F0	Complement Flag 0	1	1
CLR F1	Clear F1 Flag	1	1
CPL F1	Complement F1 Flag	1	1
Branch			
JMP addr	Jump unconditional	2	2
JMPP @A	Jump indirect	1	2
DJNZ Rr,addr	Decrement register and jump	2	2
JC addr	Jump on Carry=1	2	2
JNC addr	Jump on Carry=0	2	2
JZ addr	Jump on A Zero	2	2
JNZ addr	Jump on A not Zero	2	2
JT0 addr	Jump on T0=1	2	2
JNT0 addr	Jump on T0=0	2	2
JT1 addr	Jump on T1=1	2	2
JNT1 addr	Jump on T1=0	2	2
JF0 addr	Jump on F0 Flag=1	2	2
JF1 addr	Jump on F1 Flag=1	2	2
JTF addr	Jump on Timer Flag=1, Clear Flag	2	2
JN1BF addr	Jump on IBF Flag=0	2	2
JOBF addr	Jump on OBF Flag=1	2	2
JBb addr	Jump on Accumulator Bit	2	2

The 8041A/8741A is available currently from Intel. The upgrade to the 8041AH will be available beginning Q4'82. Contact your Intel Field Sales Engineer for details.

intel®

8041AH/8041AH-2/8641A/8741A UNIVERSAL PERIPHERAL INTERFACE 8-BIT MICROCOMPUTER

- 8041AH-2: 12 MHz
  8041AH: 8 MHz
- 8-Bit CPU plus ROM, RAM, I/O, Timer and Clock in a Single Package
- One 8-Bit Status and Two Data Registers for Asynchronous Slave-to-Master Interface
- DMA, Interrupt, or Polled Operation Supported
- 1024 x 8 ROM/EPROM, 64 x 8 RAM, 8-Bit Timer/Counter, 18 Programmable I/O Pins
- Fully Compatible with MCS-48™, MCS-80™, MCS-85™, and iAPX-86,88 Microprocessor Families
- Interchangeable ROM and EPROM Versions
- Expandable I/O
- RAM Power-Down Capability
- Over 90 Instructions: 70% Single Byte
- Single 5V Supply

The Intel® 8041AH/8741A is a general-purpose, programmable interface device designed for use with a variety of 8-bit microprocessor systems. It contains a low cost microcomputer with program memory, data memory, 8-bit CPU, I/O ports, timer/counter, and clock in a single 40-pin package. Interface registers are included to enable the UPI device to function as a peripheral controller in MCS-48™, MCS-80™, iAPX-85™, iAPX-86, iAPX-88, and other 8- or 16-bit systems.

The UPI-41A™ has 1K words of program memory and 64 words of data memory on-chip. To allow full user flexibility the program memory is available as ROM in the 8041AH version or as UV-erasable EPROM in the 8741A version. The 8741A and the 8041AH are fully pin compatible for easy transition from prototype to production level designs. The 8741A is a one-time programmable (at the factory) 8741A which can be ordered as the first 25 pieces of a new 8041AH order. The substitution of 8641As for 8041AHs allows for very fast turnaround for initial code verification and evaluation results.

The device has two 8-bit, TTL-compatible I/O ports and two test inputs. Individual port lines can function as either inputs or outputs under software control. I/O can be expanded with the 8243 device which is directly compatible and has 16 I/O lines. An 8-bit programmable timer/counter is included in the UPI device for generating timing sequences or counting external inputs. Additional UPI features include: single 5V supply, low power standby mode (in the 8041AH), single-step mode for debug and dual working register banks.

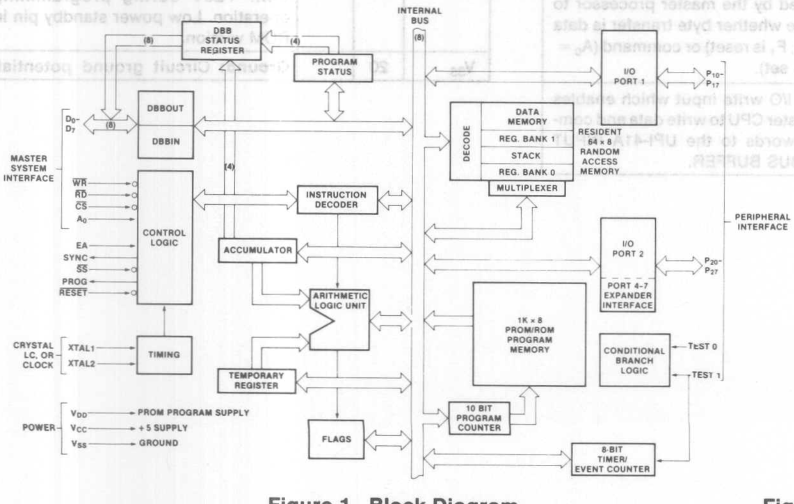


Figure 1. Block Diagram

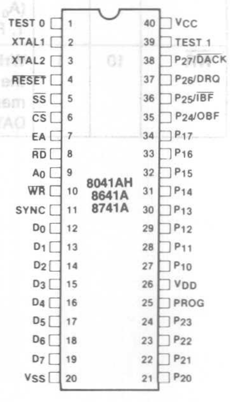


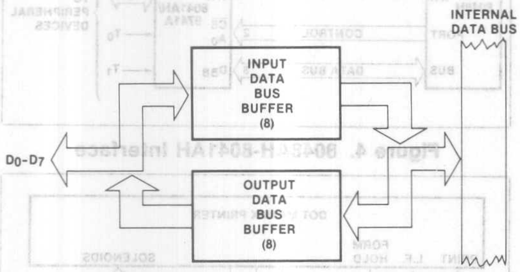
Figure 2. Pin Configuration

Table 1. Pin Description

Symbol	Pin No.	Type	Name and Function
TEST 0, TEST 1	1 39	I	**Test Inputs:** Input pins which can be directly tested using conditional branch instructions. **Frequency Reference:** TEST 1 (T_1) also functions as the event timer input (under software control). TEST 0 (T_0) is used during PROM programming and verification in the 8741A.
XTAL 1, XTAL 2	2 3	I	**Inputs:** Inputs for a crystal, LC or an external timing signal to determine the internal oscillator frequency.
RESET	4	I	**Reset:** Input used to reset status flip-flops and to set the program counter to zero. $\overline{\text{RESET}}$ is also used during PROM programming and verification.
$\overline{\text{SS}}$	5	I	**Single Step:** Single step input used in the 8741A in conjunction with the SYNC output to step the program through each instruction.
$\overline{\text{CS}}$	6	I	**Chip Select:** Chip select input used to select one UPI-41A microcomputer out of several connected to a common data bus.
EA	7	I	**External Access:** External access input which allows emulation, testing and PROM/ROM verification. This pin should be tied low if unused.
$\overline{\text{RD}}$	8	I	**Read:** I/O read input which enables the master CPU to read data and status words from the OUTPUT DATA BUS BUFFER or status register.
A_0	9	I	**Command/Data Select:** Address input used by the master processor to indicate whether byte transfer is data ($A_0 = 0$, F_1 is reset) or command ($A_0 = 1$, F_1 is set).
$\overline{\text{WR}}$	10	I	**Write:** I/O write input which enables the master CPU to write data and command words to the UPI-41A INPUT DATA BUS BUFFER.
SYNC	11	O	**Output Clock:** Output signal which occurs once per UPI-41A instruction cycle. SYNC can be used as a strobe for external circuitry; it is also used to synchronize single step operation.
D_0-D_7 (BUS)	12-19	I/O	**Data Bus:** Three-state, bidirectional DATA BUS BUFFER lines used to interface the UPI-41A microcomputer to an 8-bit master system data bus.
P_{10}-P_{17}	27-34	I/O	**Port 1:** 8-bit, PORT 1 quasi-bidirectional I/O lines.
P_{20}-P_{27}	21-24 35-38	I/O	**Port 2:** 8-bit, PORT 2 quasi-bidirectional I/O lines. The lower 4 bits (P_{20}-P_{23}) interface directly to the 8243 I/O expander device and contain address and data information during PORT 4-7 access. The upper 4 bits (P_{24}-P_{27}) can be programmed to provide interrupt Request and DMA Handshake capability. Software control can configure P_{24} as Output Buffer Full (OBF) interrupt, P_{25} as Input Buffer Full ($\overline{\text{IBF}}$) interrupt, P_{26} as DMA Request (DRQ), and P_{27} as DMA ACKnowledge ($\overline{\text{DACK}}$).
PROG	25	I/O	**Program:** Multifunction pin used as the program pulse input during PROM programming. During I/O expander access the PROG pin acts as an address/data strobe to the 8243. This pin should be tied high if unused.
V_{CC}	40		**Power:** +5V main power supply pin.
V_{DD}	26		**Power:** +5V during normal operation. +25V during programming operation. Low power standby pin in ROM version.
V_{SS}	20		**Ground:** Circuit ground potential.

UPI-41A™ FEATURES AND ENHANCEMENTS

1. Two Data Bus Buffers, one for input and one for output. This allows a much cleaner Master/Slave protocol.



2. 8 Bits of Status

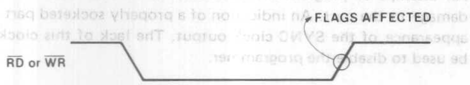
ST_7	ST_6	ST_5	ST_4	F_1	F_0	IBF	OBF
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

ST_4-ST_7 are user definable status bits. These bits are defined by the "MOV STS, A" single byte, single cycle instruction. Bits 4-7 of the accumulator are moved to bits 4-7 of the status register. Bits 0-3 of the status register are not affected.

MOV STS, A Op Code: 90H

D_7							D_0
1	0	0	1	0	0	0	0

3. $\overline{RD}$ and $\overline{WR}$ are edge triggered. IBF, OBF, F_1 and INT change internally after the trailing edge of $\overline{RD}$ or $\overline{WR}$.

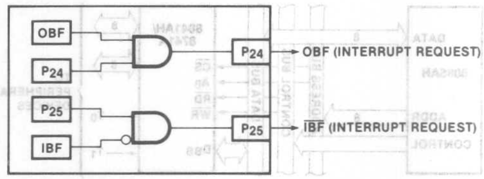


During the time that the host CPU is reading the status register, the 8041AH is prevented from updating this register or is 'locked out.'

4. P_{24} and P_{25} are port pins or Buffer Flag pins which can be used to interrupt a master processor. These pins default to port pins on Reset.

   If the "EN FLAGS" instruction has been executed, P_{24} becomes the OBF (Output Buffer Full) pin. A "1" written to P_{24} enables the OBF pin (the pin outputs the OBF Status Bit). A "0" written to P_{24} disables the OBF pin (the pin remains low). This pin can be used to indicate that valid data is available from the UPI-41A (in Output Data Bus Buffer).

   If "EN FLAGS" has been executed, P_{25} becomes the $\overline{IBF}$ (Input Buffer Full) pin. A "1" written to P_{25} enables the $\overline{IBF}$ pin (the pin outputs the inverse of the IBF Status Bit). A "0" written to P_{25} disables the $\overline{IBF}$ pin (the pin remains low). This pin can be used to indicate that the UPI-41A is ready for data.



DATA BUS BUFFER INTERRUPT CAPABILITY

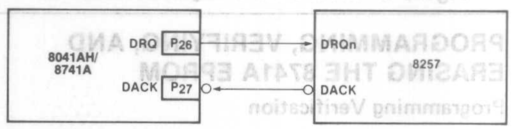
EN FLAGS Op Code: 0F5H

D_7							D_0
1	1	1	1	0	1	0	1

5. P_{26} and P_{27} are port pins or DMA handshake pins for use with a DMA controller. These pins default to port pins on Reset.

   If the "EN DMA" instruction has been executed, P_{26} becomes the DRQ (DMA ReQuest) pin. A "1" written to P_{26} causes a DMA request (DRQ is activated). DRQ is deactivated by DACK·RD, DACK·WR, or execution of the "EN DMA" instruction.

   If "EN DMA" has been executed, P_{27} becomes the $\overline{DACK}$ (DMA ACKnowledge) pin. This pin acts as a chip select input for the Data Bus Buffer registers during DMA transfers.



DMA HANDSHAKE CAPABILITY

EN DMA Op Code: 0E5H

D_7							D_0
1	1	1	0	0	1	0	1

8041AH ENHANCEMENTS OVER 8041A

1. The RESET input on the 8041AH was changed to include a 2 stage synchronizer to support reliable reset operation for 12 MHz operation.
2. As noted in the status register description, during the time that the host CPU is reading the status register, the 8041AH is prevented from updating or is 'locked out.'
3. When EA is enabled on the 8041A, the program counter is placed on Port 1 and the lower two bits of Port 2. On the 8041AH, this information is multiplexed with PORT DATA (see port timing diagrams at end of this data sheet).
4. The 8041AH additionally supports single step mode as described in the pin description section.

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APPLICATIONS

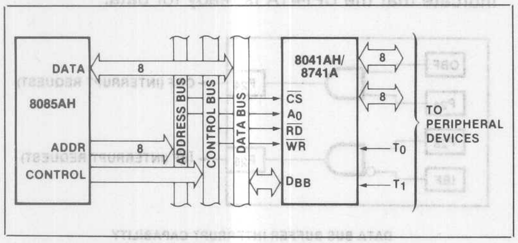

Figure 3. 8085AH-8041AH Interface

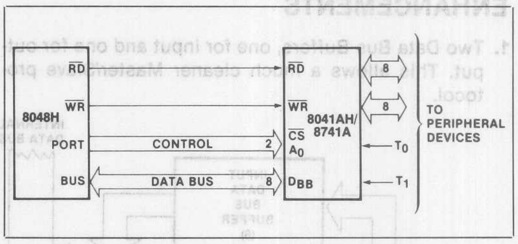

Figure 4. 8048AH-8041AH Interface

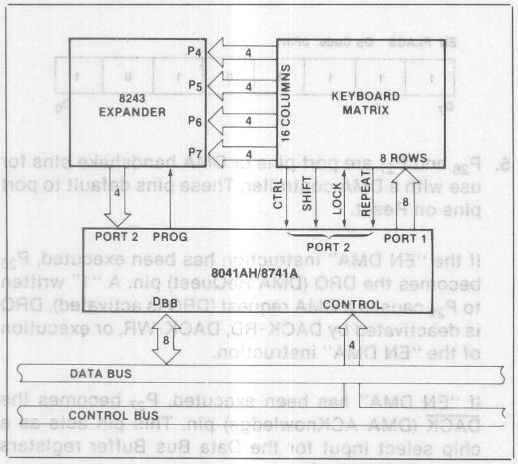

Figure 5. 8041AH-8243 Keyboard Scanner

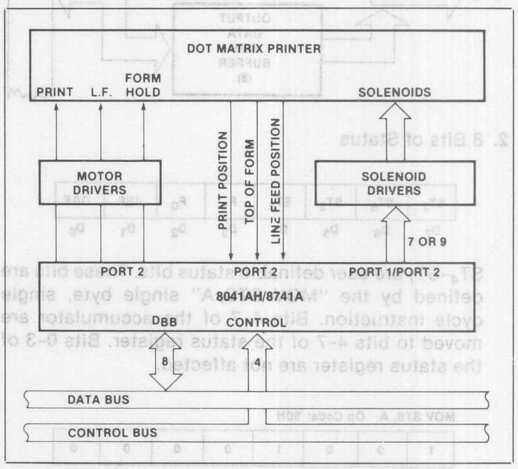

Figure 6. 8041AH Matrix Printer Interface

PROGRAMMING, VERIFYING, AND ERASING THE 8741A EPROM

Programming Verification

In brief, the programming process consists of: activating the program mode, applying an address, latching the address, applying data, and applying a programming pulse. Each word is programmed completely before moving on to the next and is followed by a verification step. The following is a list of the pins used for programming and a description of their functions:

Pin	Function
XTAL 1	Clock Input (1 to 6MHz)
$\overline{\text{Reset}}$	Initialization and Address Latching
Test 0	Selection of Program or Verify Mode
EA	Activation of Program/Verify Modes
BUS	Address and Data Input Data Output During Verify
P20-1	Address Input
V_{DD}	Programming Power Supply
PROG	Program Pulse Input

WARNING:
An attempt to program a missocketed 8741A will result in severe damage to the part. An indication of a properly socketed part is the appearance of the SYNC clock output. The lack of this clock may be used to disable the programmer.

The Program/Verify sequence is:

1. A_0 = 0V, $\overline{CS}$ = 5V, EA = 5V, $\overline{RESET}$ = 0V, TEST0 = 5V, V_{DD} = 5V, clock applied or internal oscillator operating, BUS and PROG floating.
2. Insert 8741A in programming socket
3. TEST 0 = 0v (select program mode)
4. EA = 23V (activate program model)[1]
5. Address applied to BUS and P20-1
6. $\overline{RESET}$ = 5v (latch address)
7. Data applied to BUS[2]
8. V_{DD} = 25v (programming power)[2]
9. PROG = 0v followered by one 50ms pulse to 23V[2]
10. V_{DD} = 5v
11. TEST 0 = 5v (verify mode)

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12. Read and verify data on BUS
13. TEST 0 = 0v
14. $\overline{\text{RESET}}$ = 0v and repeat from step 5
15. Programmer should be at conditions of step 1 when 8741A is removed from socket.

NOTE:
1. When verifying ROM, EA = 12V.
2. Not used in verify ROM procedure.

8741A Erasure Characteristics

The erasure characteristics of the 8741A are such that erasure begins to occur when exposed to light with wavelengths shorter than approximately 4000 Angstroms (Å). It should be noted that sunlight and certain types of fluorescent lamps have wavelengths in the 3000–4000Å range. Data show that constant exposure to room level fluorescent lighting could erase the typical 8741A in approximately 3 years while it would take approximately one week to cause erasure when exposed to direct sunlight. If the 8741A is to be exposed to these types of lighting conditions for extended periods of time, opaque labels are available from Intel which should be placed over the 8741A window to prevent unintentional erasure.

The recommended erasure procedure for the 8741A is exposure to shortwave ultraviolet light which has a wavelength of 2537Å. The integrated dose (i.e., UV intensity x exposure time) for erasure should be a minimum of 15 w-sec/cm^2. The erasure time with this dosage is approximately 15 to 20 minutes using an ultraviolet lamp with a 12,000 μW/cm^2 power rating. The 8741A should be placed within one inch of the lamp tubes during erasure. Some lamps have a filter on their tubes which should be removed before erasure.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias .... 0°C to 70°C
Storage Temperature .... −65°C to +150°C
Voltage on Any Pin With Respect
to Ground .... −0.5V to +7V
Power Dissipation .... 1.5 Watt

**NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. CHARACTERISTICS ($T_A = 0°$ to $+70°C$, $V_{CC} = V_{DD} = +5V \pm 10\%$)

Symbol	Parameter	8041AH/ 8041AH-2		8641A/8741A		Units	Test Conditions
		Min.	Max.	Min.	Max.		
V_{IL}	Input Low Voltage (Except XTAL1, XTAL2, $\overline{RESET}$	−0.5	0.8	−0.5	0.8	V	
V_{IL1}	Input Low Voltage (8XTAL1, XTAL2, $\overline{RESET}$)	−0.5	0.6	−0.5	0.6	V	
V_{IH}	Input High Voltage (Except XTAL1, XTAL2, $\overline{RESET}$	2.0	V_{CC}	2.0	V_{CC}		
V_{IH1}	Input High Voltage (XTAL1, XTAL2, $\overline{RESET}$)	3.8	V_{CC}	3.8	V_{CC}	V	
V_{OL}	Output Low Voltage (D_0-D_7)		0.45		0.45	V	$I_{OL} = 2.0$ mA
V_{OL1}	Output Low Voltage ($P_{10}P_{17}$, $P_{20}P_{27}$, Sync)		0.45		0.45	V	$I_{OL} = 1.6$ mA
V_{OL2}	Output Low Voltage (Prog)		0.45		0.45	V	$I_{OL} = 1.0$ mA
V_{OH}	Output High Voltage (D_0-D_7)	2.4		2.4		V	$I_{OH} = -400\ \mu A$
V_{OH1}	Output High Voltage (All Other Outputs)	2.4		2.4		V	$I_{OH} = -50\ \mu A$
I_{IL}	Input Leakage Current (T_0, T_1, $\overline{RD}$, $\overline{WR}$, $\overline{CS}$, A_0, EA)		±10		±10	μA	$V_{SS} \leq V_{IN} \geq V_{CC}$
I_{OFL}	Output Leakage Current (D_0-D_7, High Z State)		±10		±10	μA	$V_{SS} + 0.45 \leq V_{OUT} \leq V_{CC}$
I_{LI}	Low Input Load Current ($P_{10}P_{17}$, $P_{20}P_{27}$)		0.5		0.5	mA	$V_{IL} = 0.8$ V
I_{LI1}	Low Input Load Current ($\overline{RESET}$, $\overline{SS}$)		0.2		0.2	mA	$V_{IL} = 0.8$ V
I_{DD}	V_{DD} Supply Current		15		15	mA	Typical = 5 mA
$I_{CC} + I_{DD}$	Total Supply Current		125		125	mA	Typical = 60 mA
I_{IH}	Input Leakage Current		100		100	NA	$V_{IN} = V_{CC}$
C_{IN}	Input Capacitance		10		10	pF	
$C_{I/O}$	I/O Capacitance		20		20	pF	

D.C. CHARACTERISTICS—PROGRAMMING ($T_A = 25°C \pm 5°C$, $V_{CC} = 5V \pm 5\%$, $V_{DD} = 25V \pm 1V$)

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
V_{DDH}	V_{DD} Program Voltage High Level	24.0	26.0	V	
V_{DDL}	V_{DD} Voltage Low Level	4.75	5.25	V	
V_{PH}	PROG Program Voltage High Level	21.5	24.5	V	
V_{PL}	PROG Voltage Low Level		0.2	V	
V_{EAH}	EA Program or Verify Voltage High Level	21.5	24.5	V	
V_{EAL}	EA Voltage Low Level		5.25	V	
I_{DD}	V_{DD} High Voltage Supply Current		30.0	mA	
I_{PROG}	PROG High Voltage Supply Current		16.0	mA	
I_{EA}	EA High Voltage Supply Current		1.0	mA	

A.C. CHARACTERISTICS ($T_{CC} = 0°C$ to $+70°C$, $V_{SS} = 0V$, $V_{CC} = V_{DD} = +5V \pm 10\%$)

DBB READ

Symbol	Parameter	8041AH		8041AH-2		8641A/8741A		Units
		Min.	Max.	Min.	Max.	Min.	Max.	
t_{AR}	$\overline{CS}$, A_0 Setup to $\overline{RD}\downarrow$	0		0		0		ns
t_{RA}	$\overline{CS}$, A_0 Hold After $\overline{RD}\uparrow$	0		0		0		ns
t_{RR}	$\overline{RD}$ Pulse Width	160		160		250		ns
t_{AD}	$\overline{CS}$, A_0 to Data Out Delay		130		130		225	ns[1]
t_{RD}	$\overline{RD}\downarrow$ to Data Out Delay		130		130		225	ns[1]
t_{DF}	$\overline{RD}\uparrow$ to Data Float Delay		85		85		100	ns
t_{CY}	Cycle Time (Except 8741A-8)	2	15	1.25	15	2.5	15	μs[2]
t_{CY}	Cycle Time (8741A-8)					4.17	15	μs[3]

DBB WRITE

Symbol	Parameter	Min.	Max.	Min.	Max.	Min.	Max.	Units
t_{AW}	$\overline{CS}$, A_0 Setup to $\overline{WR}\downarrow$	0		0		0		ns
t_{WA}	$\overline{CS}$, A_0 Hold After $\overline{WR}\uparrow$	0		0		0		ns
t_{WW}	$\overline{WR}$ Pulse Width	160		160		250		ns
t_{DW}	Data Setup to $\overline{WR}\uparrow$	130		130		150		ns
t_{WD}	Data Hold After $\overline{WR}\uparrow$	0		0		0		ns

NOTES:
1. $C_L = 150$ pF.
2. 8, 12, 6 MHz XTAL respectively.
3. 3.6 MHz XTAL.

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A.C. CHARACTERISTICS—PROGRAMMING ($T_A = 25°C \pm 5°C$, $V_{CC} = 5V \pm 5\%$, $V_{DD} = 25V \pm 1V$)

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	Address Setup Time to $\overline{RESET}$ ↑	$4t_{CY}$			
t_{WA}	Address Hold Time After $\overline{RESET}$ ↑	$4t_{CY}$			
t_{DW}	Data in Setup Time to PROG ↑	$4t_{CY}$			
t_{WD}	Data in Hold Time After PROG ↓	$4t_{CY}$			
t_{PH}	$\overline{RESET}$ Hold Time to Verify	$4t_{CY}$			
t_{VDDW}	V_{DD} Setup Time to PROG ↑	$4t_{CY}$			
t_{VDDH}	V_{DD} Hold Time After PROG ↓	0			
t_{PW}	Program Pulse Width	50	60	mS	
t_{TW}	Test 0 Setup Time for Program Mode	$4t_{CY}$			
t_{WT}	Test 0 Hold Time After Program Mode	$4t_{CY}$			
t_{DO}	Test 0 to Data Out Delay		$4t_{CY}$		
t_{WW}	$\overline{RESET}$ Pulse Width to Latch Address	$4t_{CY}$			
t_r, t_f	V_{DD} and PROG Rise and Fall Times	0.5	2.0	μs	
t_{CY}	CPU Operation Cycle Time	5.0		μs	
t_{RE}	$\overline{RESET}$ Setup Time Before EA ↑.	$4t_{CY}$			

Note: If TEST 0 is high, t_{DO} can be triggered by $\overline{RESET}$ ↑.

A.C. CHARACTERISTICS
DMA

		8041AH		8041AH-2		8641A/8741A		
Symbol	**Parameter**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Units**
t_{ACC}	$\overline{DACK}$ to $\overline{WR}$ or $\overline{RD}$	0		0		0		ns
t_{CAC}	$\overline{RD}$ or $\overline{WR}$ to $\overline{DACK}$	0		0		0		ns
t_{ACD}	$\overline{DACK}$ to Data Valid		130		130		225	ns
t_{CRQ}	$\overline{RD}$ or $\overline{WR}$ to DRQ Cleared		90		90		200	ns[1]

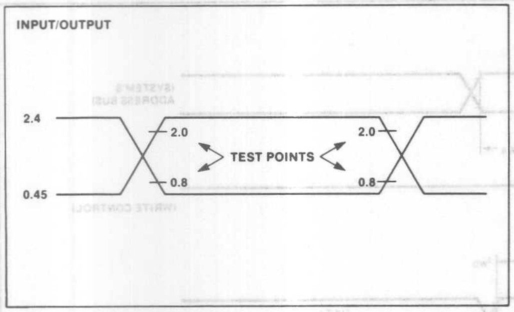
A.C. CHARACTERISTICS
PORT 2

($T_A = 0°C$ to $+70°C$, $V_{CC} = +5V \pm 10\%$)

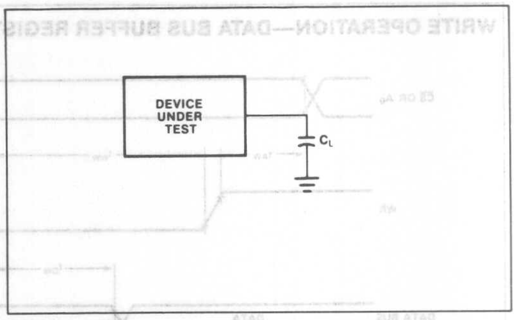
		8041AH		8041AH-2		8641A/8741A		
Symbol	**Parameter**	**Min.**	**Max.**	**Min.**	**Max.**	**Min.**	**Max.**	**Units**
t_{CP}	Port Control Setup Before Falling Edge of PROG	100		80		110		ns[1]
t_{PC}	Port Control Hold After Falling Edge of PROG			60		100		ns[2]
t_{PR}	PROG to Time P2 Input Must Be Valid		650		650		810	ns[1]
t_{PF}	Input Data Hold Time	0	150	0	150	0	150	ns[2]
t_{DP}	Output Data Setup time			200		250		ns[1]
t_{PD}	Output Data Hold Time					65		ns[2]
t_{PP}	PROG Pulse Width			700		1200		ns

NOTES: 1. $C_L = 80$ pF. 2. $C_L = 20$ pF.

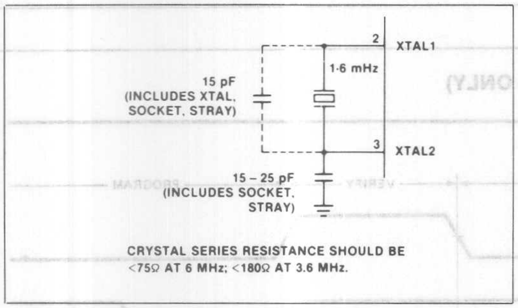
A.C. TESTING INPUT, OUTPUT WAVEFORM



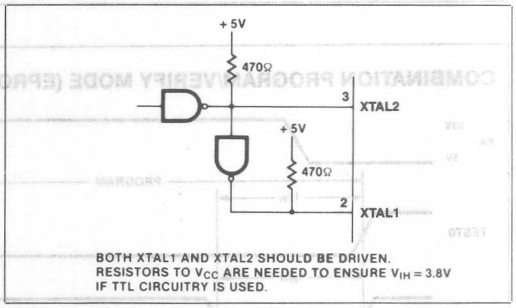
A.C. TESTING LOAD CIRCUIT



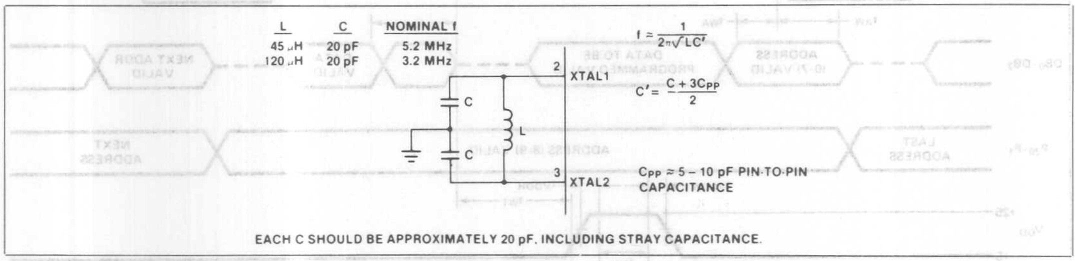
CRYSTAL OSCILLATOR MODE



DRIVING FROM EXTERNAL SOURCE

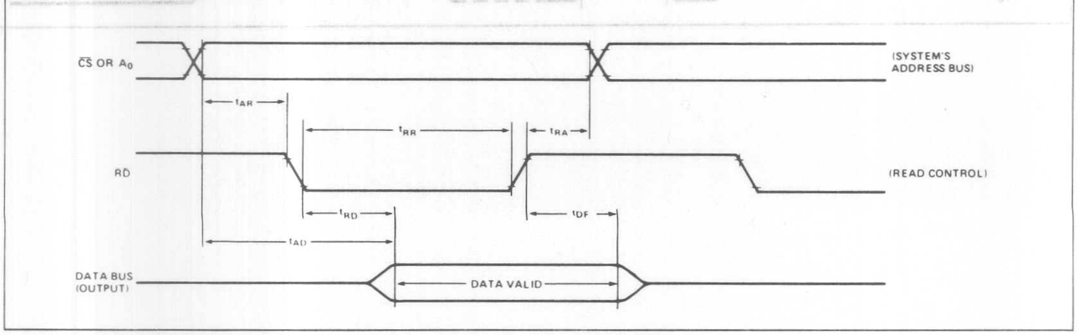


LC OSCILLATOR MODE



WAVEFORMS

READ OPERATION—DATA BUS BUFFER REGISTER



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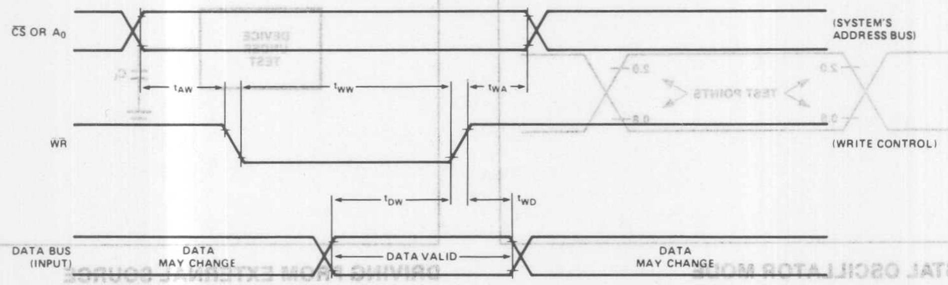
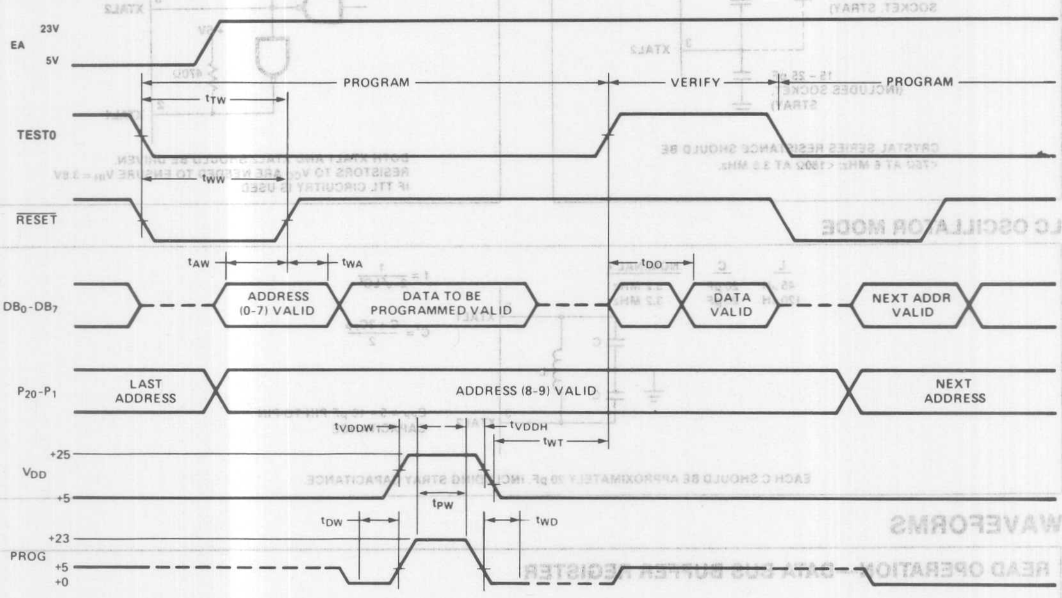
WAVEFORMS (Continued)

WRITE OPERATION—DATA BUS BUFFER REGISTER



COMBINATION PROGRAM/VERIFY MODE (EPROM'S ONLY)



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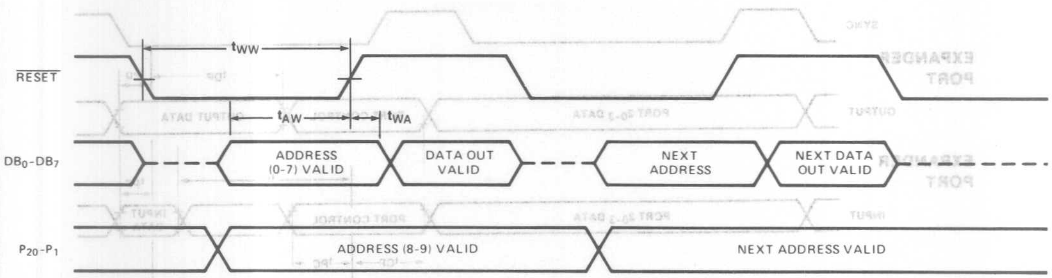
WAVEFORMS (Continued)

VERIFY MODE (ROM/EPROM)

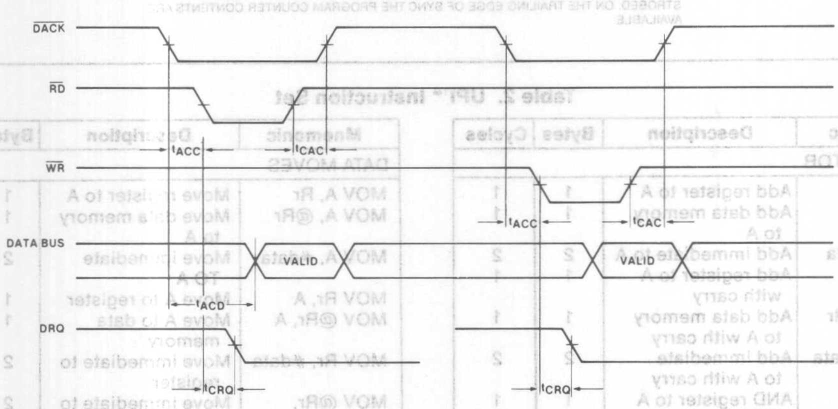


NOTES:
1. PROG MUST FLOAT IF EA IS LOW (i.e., = 23V), OR IF TO = 5V FOR THE 8741A. FOR THE 8041AH PROG MUST ALWAYS FLOAT.
2. XTAL1 and XTAL2 DRIVEN BY 3.6 MHz CLOCK WILL GIVE 4.17 μsec t_{CY}. THIS IS ACCEPTABLE FOR 8741A-8 PARTS AS WELL AS STANDARD PARTS.
3. AO MUST BE HELD LOW (i.e., = 0V) DURING PROGRAM/VERIFY MODES.
4. TEST 0 MUST BE HELD HIGH.

The 8741A EPROM can be programmed by either of two Intel products:

1. PROMPT-48 Microcomputer Design Aid, or
2. Universal PROM Programmer (UPP series) peripheral of the Intellec® Development System with a UPP-848 Personality Card.

DMA



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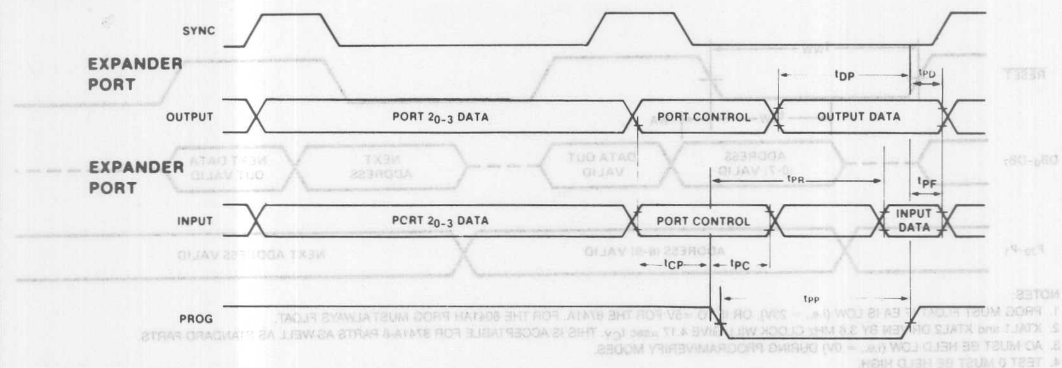
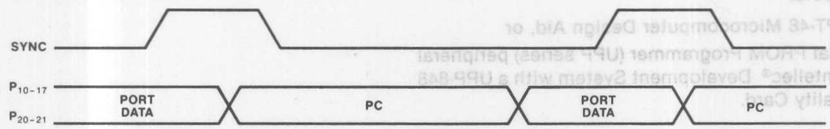
WAVEFORMS (Continued)

PORT 2



PORT TIMING DURING EA



ON THE RISING EDGE OF SYNC AND EA IS ENABLED, PORT DATA IS VALID AND CAN BE STROBED. ON THE TRAILING EDGE OF SYNC THE PROGRAM COUNTER CONTENTS ARE AVAILABLE.

Table 2. UPI™ Instruction Set

Mnemonic	Description	Bytes	Cycles
ACCUMULATOR			
ADD A, Rr	Add register to A	1	1
ADD A, @Rr	Add data memory to A	1	1
ADD A, #data	Add immediate to A	2	2
ADDC A, Rr	Add register to A with carry	1	1
ADDC A, @Rr	Add data memory to A with carry	1	1
ADDC A, #data	Add immediate to A with carry	2	2
ANL A, Rr	AND register to A	1	1
ANL A, @Rr	AND data memory to A	1	1
ANL A, #data	AND immediate to A	2	2
ORL A, Rr	OR register to A	1	1
ORL A, @Rr	OR data memory to A	1	1
ORL A, #data	OR immediate to A	2	2
XRL A, Rr	Exclusive OR register to A	1	1
XRL A, @Rr	Exclusive OR data memory to A	1	1
XRL A, #data	Exclusive OR immediate to A	2	2

Mnemonic	Description	Bytes	Cycles
DATA MOVES			
MOV A, Rr	Move register to A	1	1
MOV A, @Rr	Move data memory to A	1	1
MOV A, #data	Move immediate TO A	2	2
MOV Rr, A	Move A to register	1	1
MOV @Rr, A	Move A to data memory	1	1
MOV Rr, #data	Move immediate to register	2	2
MOV @Rr, #data	Move immediate to data memory	2	2
MOV A, PSW	Move PSW to A	1	1
MOV PSW, A	Move A to PSW	1	1
XCH A, Rr	Exchange A and register	1	1
XCH A, @Rr	Exchange A and data memory	1	1
XCHD A, @Rr	Exchange digit of A and register	1	1
MOVP A, @A	Move to A from current page	1	2
MOVP3, A, @A	Move to A from page 3	1	2

Table 2. UPI™ Instruction Set (Continued)

Mnemonic	Description	Bytes	Cycles
ACCUMULATOR			
INC A	Increment A	1	1
DEC A	Decrement A	1	1
CLR A	Clear A	1	1
CPL A	Complement A	1	1
DA A	Decimal Adjust A	1	1
SWAP A	Swap nibbles of A	1	1
RL A	Rotate A left	1	1
RLC A	Rotate A left through carry	1	1
RR A	Rotate A right	1	1
RRC A	Rotate A right through carry	1	1
INPUT/OUTPUT			
IN A, Pp	Input port toA	1	2
OUTL Pp, A	Output A to port	1	2
ANL Pp, #data	AND immediate to port	2	2
ORL Pp, #data	OR immediate to port	2	2
IN A, DBB	Input DBB to A, clear IBF	1	1
OUT DBB, A	Output A to DBB, set OBF	1	1
MOV STS, A	A_4–A_7 to Bits 4–7 of Status	1	1
MOVD A, Pp	Input Expander port to A	1	2
MOVD Pp, A	Output A to Expander port	1	2
ANLD Pp, A	AND A to Expander port	1	2
ORLD Pp, A	OR A to Expander port	1	2
TIMER/COUNTER			
MOV A, T	Read Timer/Counter	1	1
MOV T, A	Load Timer/Counter	1	1
STRT T	Start Timer	1	1
STRT CNT	start Counter	1	1
STOP TCNT	Stop Timer/Counter	1	1
EN TCNTI	Enable Timer/ Counter Interrupt	1	1
DIS TCNTI	Disable Timer/ Counter Interrupt	1	1
CONTROL			
EN DMA	Enable DMA Hand-shake Lines	1	1
EN I	Enable IBF Interrupt	1	1
DIS I	Disable IBF Inter-rupt	1	1
EN FLAGS	Enable Master Interrupts	1	1
SEL RB0	Select register bank 0	1	1
SEL RB1	Select register bank 1	1	1
NOP	No Operation	1	1

Mnemonic	Description	Bytes	Cycles
REGISTERS			
INC Rr	Increment register	1	1
INC @Rr	Increment data memory	1	1
DEC Rr	Decrement register	1	1
SUBROUTINE			
CALL addr	Jump to subroutine	2	2
RET	Return	1	2
RETR	Return and restore status	1	2
FLAGS			
CLR C	Clear Carry	1	1
CPL C	Complement Carry	1	1
CLR F0	Clear Flag 0	1	1
CPL F0	Complement Flag 0	1	1
CLR F1	Clear F1 Flag	1	1
CPL F1	Complement F1 Flag	1	1
BRANCH			
JMP addr	Jump unconditional	2	2
JMPP @A	Jump indirect	1	2
DJNZ Rr, addr	Decrement register and jump	2	2
JC addr	Jump on Carry=1	2	2
JNC addr	Jump on Carry=0	2	2
JZ addr	Jump on A Zero	2	2
JNZ addr	Jump on A not Zero	2	2
JT0 addr	Jump on T0=1	2	2
JNT0 addr	Jump on T0=0	2	2
JT1 addr	Jump on T1=1	2	2
JNT1 addr	Jump on T1=0	2	2
JF0 addr	Jump on F0 Flag=1	2	2
JF1 addr	Jump on F1 Flag=1	2	2
JTF addr	Jump on Timer Flag =1, Clear Flag	2	2
JNIBF addr	Jump on IBF Flag =0	2	2
JOBF addr	Jump on OBF Flag =1	2	2
JBb addr	Jump on Accumula-tor Bit	2	2

UNIVERSAL PERIPHERAL INTERFACE 8-BIT MICROCOMPUTER

- 8042/8742: 12 MHz
- Pin, Software and Architecturally Compatible with 8041A/8741A/8041AH
- 8-Bit CPU plus ROM, RAM, I/O, Timer and Clock in a Single Package
- 2048 × 8 ROM/EPROM, 128 × 8 RAM, 8-Bit Timer/Counter, 18 Programmable I/O Pins
- One 8-Bit Status and Two Data Registers for Asynchronous Slave-to-Master Interface
- DMA, Interrupt, or Polled Operation Supported
- Fully Compatible with MCS-48™, MCS-51™, MCS-80™, MCS-85™, and iAPX-86, 88 Microprocessor Families
- Interchangeable ROM and EPROM Versions
- Expandable I/O
- RAM Power-Down Capability
- Over 90 Instructions: 70% Single Byte
- Single 5V Supply

The Intel 8042/8742 is a general-purpose Universal Peripheral Interface that allows the designer to grow his own customized solution for peripheral device control. It contains a low-cost microcomputer with 2K of program memory, 128 bytes of data memory, 8-bit CPU, I/O ports, 8-bit timer/counter, and clock generator in a single 40-pin package. Interface registers are included to enable the UPI device to function as a peripheral controller in the MCS-48™, MCS-51™, MCS-80™, MCS-85™, iAPX-88, iAPX-86 and other 8-, 16-bit systems.

The 8042/8742 is software, pin, and architecturally compatible with the 8041AH, 8741A. The 8042/8742 doubles the on-chip memory space to allow for additional features and performance to be incorporated in upgraded 8041AH/8741A designs. For new designs, the additional memory and performance of the 8042/8742 extends the UPI concept to more complex motor control tasks, 80-column printers and process control applications as examples.

To allow full user flexibility, the program memory is available as ROM in the 8042 version or as UV-erasable EPROM in the 8742 version. The 8742 and the 8042 are fully pin compatible for easy transition from prototype to production level designs. The 8642 is a one-time programmable (at the factory) 8742 which can be ordered as the first 25 pieces of a new 8042 order. The substitution of 8642's for 8042's allows for very fast turnaround for initial code verification and evaluation results.

The device has two 8-bit, TTL compatible I/O ports and two test inputs. Individual port lines can function as either inputs or outputs under software control. I/O can be expanded with the 8243 device which is directly compatible and has 16 I/O lines. An 8-bit programmable timer/counter is included in the UPI device for generating timing sequences or counting external inputs. Additional UPI features include: single 5V supply, low power standby mode (in the 8042), single-step mode for debug, and dual working register banks.

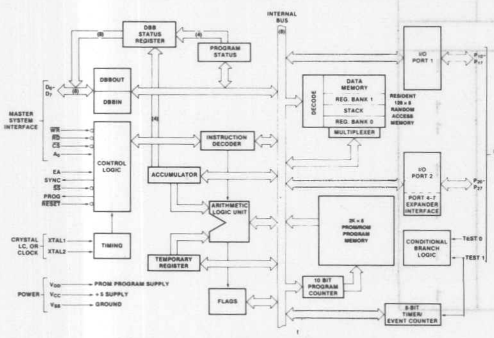


Figure 1. Block Diagram

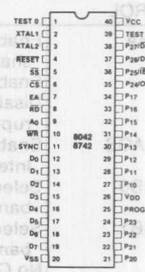


Figure 2. Pin Configuration

MARCH 1982
ORDER NUMBER: 210393-002

Table 1. Pin Description

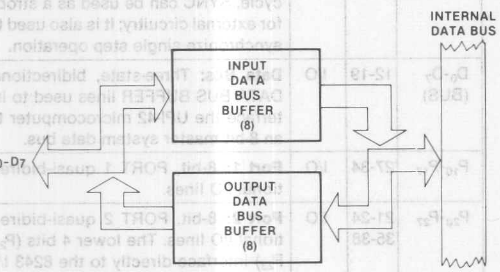
Symbol	Pin No.	Type	Name and Function
TEST 0, TEST 1	1 39	I	**Test Inputs:** Input pins which can be directly tested using conditional branch instructions. **Frequency Reference:** TEST 1 (T_1) also functions as the event timer input (under software control). TEST 0 (T_0) is used during PROM programming and verification in the 8742.
XTAL 1, XTAL 2	2 3	I	**Inputs:** Inputs for a crystal, LC or an external timing signal to determine the internal oscillator frequency.
$\overline{RESET}$	4	I	**Reset:** Input used to reset status flip-flops and to set the program counter to zero. $\overline{RESET}$ is also used during PROM programming and verification.
$\overline{SS}$	5	I	**Single Step:** Single step input used in conjunction with the SYNC output to step the program through each instruction.
$\overline{CS}$	6	I	**Chip Select:** Chip select input used to select one UPI microcomputer out of several connected to a common data bus.
EA	7	I	**External Access:** External access input which allows emulation, testing and PROM/ROM verification. This pin should be tied low if unused.
$\overline{RD}$	8	I	**Read:** I/O read input which enables the master CPU to read data and status words from the OUTPUT DATA BUS BUFFER or status register.
A_0	9	I	**Command/Data Select:** Address input used by the master processor to indicate whether byte transfer is data (A_0=0, F1 is reset) or command (A_0=1, F1 is set).
$\overline{WR}$	10	I	**Write:** I/O write input which enables the master CPU to write data and command words to the UPI INPUT DATA BUS BUFFER.

Symbol	Pin No.	Type	Name and Function
SYNC	11	O	**Output Clock:** Output signal which occurs once per UPI-42 instruction cycle. SYNC can be used as a strobe for external circuitry; it is also used to synchronize single step operation.
D_0-D_7 (BUS)	12-19	I/O	**Data Bus:** Three-state, bidirectional DATA BUS BUFFER lines used to interface the UPI-42 microcomputer to an 8-bit master system data bus.
P_{10}-P_{17}	27-34	I/O	**Port 1:** 8-bit, PORT 1 quasi-bidirectional I/O lines.
P_{20}-P_{27}	21-24 35-38	I/O	**Port 2:** 8-bit, PORT 2 quasi-bidirectional I/O lines. The lower 4 bits (P_{20}-P_{23}) interface directly to the 8243 I/O expander device and contain address and data information during PORT 4-7 access. The upper 4 bits (P_{24}-P_{27}) can be programmed to provide interrupt Request and DMA Handshake capability. Software control can configure P_{24} as Output Buffer Full (OBF) interrupt, P_{25} as Input Buffer Full ($\overline{IBF}$) interrupt, P_{26} as DMA Request (DRQ), and P_{27} as DMA ACKnowledge ($\overline{DACK}$).
PROG	25	I/O	**Program:** Multifunction pin used as the program pulse input during PROM programming. During I/O expander access the PROG pin acts as an address/data strobe to the 8243. This pin should be tied high if unused.
V_{CC}	40		**Power:** +5V main power supply pin.
V_{DD}	26		**Power:** +5V during normal operation. +21V during programming operation. Low power standby pin in ROM version.
V_{SS}	20		**Ground:** Circuit ground potential.

AFN-01832A

UPI-42 FEATURES

1. Two Data Bus Buffers, one for input and one for output. This allows a much cleaner Master/Slave protocol.



2. 8 Bits of Status

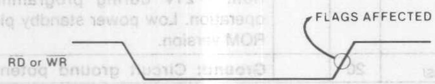
ST_7	ST_6	ST_5	ST_4	F_1	F_0	IBF	OBF
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

ST_4-ST_7 are user definable status bits. These bits are defined by the "MOV STS, A" single byte, single cycle instruction. Bits 4-7 of the accumulator are moved to bits 4-7 of the status register. Bits 0-3 of the status register are not affected.

MOV STS. A Op Code: 90H

1	0	0	1	0	0	0	0
D_7							D_0

3. $\overline{RD}$ and $\overline{WR}$ are edge triggered. IBF, OBF, F_1 and INT change internally after the trailing edge of $\overline{RD}$ or $\overline{WR}$.

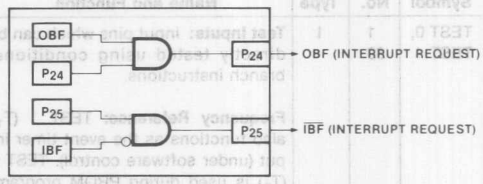


During the time that the host CPU is reading the status register, the 8042/8742 is prevented from updating this register or is 'locked out.'

4. P_{24} and P_{25} are port pins or Buffer Flag pins which can be used to interrupt a master processor. These pins default to port pins on Reset.

   If the "EN FLAGS" instruction has been executed, P_{24} becomes the OBF (Output Buffer Full) pin. A "1" written to P_{24} enables the OBF pin (the pin outputs the OBF Status Bit). A "0" written to P_{24} disables the OBF pin (the pin remains low). This pin can be used to indicate that valid data is available from the UPI-41A (in Output Data Bus Buffer).

   If "EN FLAGS" has been executed, P_{25} becomes the $\overline{IBF}$ (Input Buffer Full) pin. A "1" written to P_{25} enables the $\overline{IBF}$ pin (the pin outputs the inverse of the IBF Status Bit). A "0" written to P_{25} disables the $\overline{IBF}$ pin (the pin remains low). This pin can be used to indicate that the UPI-42 is ready for data.



DATA BUS BUFFER INTERRUPT CAPABILITY

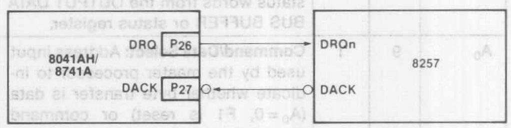
EN FLAGS Op Code: 0F5H

1	1	1	1	0	1	0	1
D_7							D_0

5. P_{26} and P_{27} are port pins or DMA handshake pins for use with a DMA controller. These pins default to port pins on Reset.

   If the "EN DMA" instruction has been executed, P_{26} becomes the DRQ (DMA ReQuest) pin. A "1" written to P_{26} causes a DMA request (DRQ is activated). DRQ is deactivated by DACK·RD, DACK·WR, or execution of the "EN DMA" instruction.

   If "EN DMA" has been executed, P_{27} becomes the $\overline{DACK}$ (DMA ACKnowledge) pin. This pin acts as a chip select input for the Data Bus Buffer registers during DMA transfers.



DMA HANDSHAKE CAPABILITY

EN DMA Op Code: 0E5H

1	1	1	0	0	1	0	1
D_1							D_0

6. The RESET input on the 8042/8742 includes a 2-stage synchronizer to support reliable reset operation for 12 MHz operation.

7. When EA is enabled on the 8042/8742, the program counter is placed on Port 1 and the lower three bits of Port 2 (MSB = P_{22}, LSB = P_{10}). On the 8042/8742 this information is multiplexed with PORT DATA (see port timing diagrams at end of this data sheet).

8. The 8042/8742 supports single step mode as described in the pin description section.

APPLICATIONS

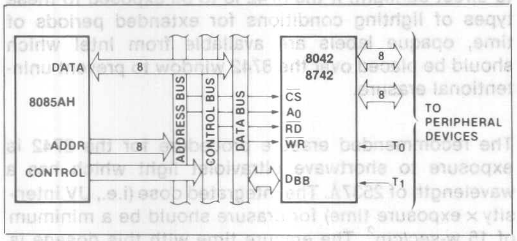


Figure 3. 8085AH-8042/8742 Interface

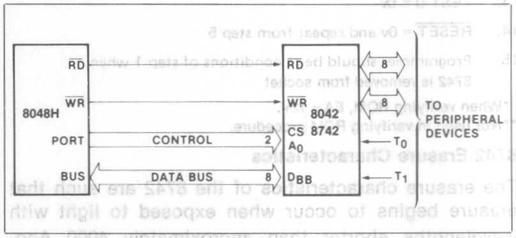


Figure 4. 8048H-8042/8742 Interface

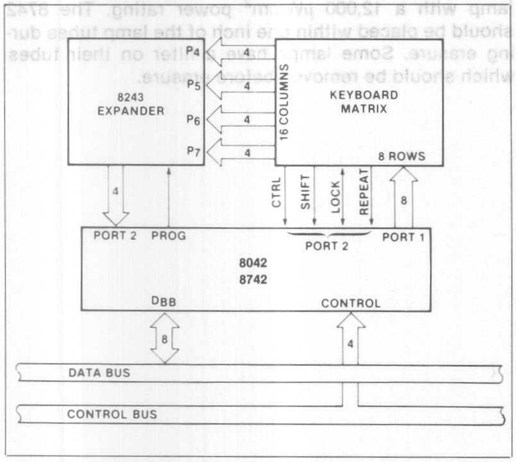


Figure 5. 8042/8742-8243 Keyboard Scanner

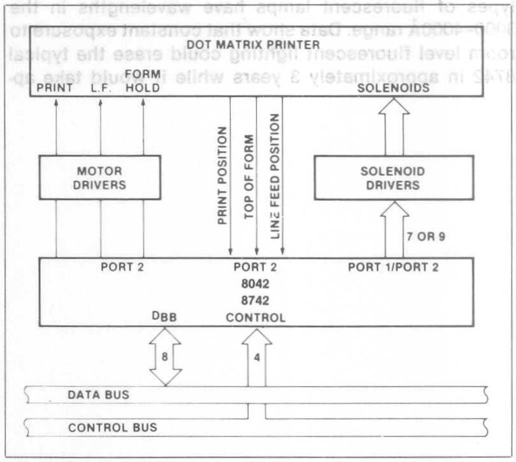


Figure 6. 8042/8742 80-Column Matrix Printer Interface

PROGRAMMING, VERIFYING, AND ERASING THE 8742 EPROM

Programming Verification

In brief, the programming process consists of: activating the program mode, applying an address, latching the address, applying data, and applying a programming pulse. Each word is programmed completely before moving on to the next and is followed by a verification step. The following is a list of the pins used for programming and a description of their functions:

Pin	Function
XTAL 1	Clock Input (1 to 12MHz)
$\overline{\text{Reset}}$	Initialization and Address Latching
Test 0	Selection of Program or Verify Mode
EA	Activation of Program/Verify Modes
BUS	Address and Data Input Data Output During Verify
P20-1	Address Input
V_{DD}	Programming Power Supply
PROG	Program Pulse Input

WARNING

An attempt to program a missocketed 8742 will result in severe damage to the part. An indication of a properly socketed part is the appearance of the SYNC clock output. The lack of this clock may be used to disable the programmer.

The Program/Verify sequence is:

1. A_0 = 0V, $\overline{CS}$ = 5V, EA = 5V, $\overline{RESET}$ = 0V, TEST0 = 5V, V_{DD} = 5V, clock applied or internal oscillator operating, BUS and PROG floating.
2. Insert 8742 in programming socket
3. TEST 0 = 0v (select program mode)
4. EA = 18V (active program mode)*
5. Address applied to BUS and $P_{20\text{-}22}$
6. $\overline{RESET}$ = 5v (latch address)
7. Data applied to BUS**
8. V_{DD} = 20V (programming power)**
9. PROG = 0v followed by one 50 ms pulse to 18V**
10. V_{DD} = 5v
11. TEST 0 = 5v (verify mode)

12. Read and verify data on BUS
13. TEST 0 = 0v
14. $\overline{\text{RESET}}$ = 0v and repeat from step 5
15. Programmer should be at conditions of step 1 when 8742 is removed from socket

*When verifying ROM, EA = 12V.
**Not used in verifying ROM procedure.

8742 Erasure Characteristics

The erasure characteristics of the 8742 are such that erasure begins to occur when exposed to light with wavelengths shorter than approximately 4000 Angstroms (Å). It should be noted that sunlight and certain types of fluorescent lamps have wavelengths in the 3000–4000Å range. Data show that constant exposure to room level fluorescent lighting could erase the typical 8742 in approximately 3 years while it would take approximately one week to cause erasure when exposed to direct sunlight. If the 8742 is to be exposed to these types of lighting conditions for extended periods of time, opaque labels are available from Intel which should be placed over the 8742 window to prevent unintentional erasure.

The recommended erasure procedure for the 8742 is exposure to shortwave ultraviolet light which has a wavelength of 2537Å. The integrated dose (i.e., UV intensity × exposure time) for erasure should be a minimum of 15 w-sec/cm^2. The erasure time with this dosage is approximately 15 to 20 minutes using an ultraviolet lamp with a 12,000 μW/cm^2 power rating. The 8742 should be placed within one inch of the lamp tubes during erasure. Some lamps have a filter on their tubes which should be removed before erasure.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias ....0°C to 70°C
Storage Temperature .... −65°C to +150°C
Voltage on Any Pin With Respect
to Ground .... −0.5V to +7V
Power Dissipation .... 1.5 Watt

*NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS ($T_A = 0°$ to $+70°C$, $V_{CC} = V_{DD} = +5V \pm 10\%$)

Symbol	Parameter	8042 Min.	8042 Max.	8742/8642 Min.	8742/8642 Max.	Units	Notes
V_{IL}	Input Low Voltage (Except XTAL1, XTAL2, RESET)	−0.5	0.8	−0.5	0.8	V	
V_{IL1}	Input Low Voltage (XTAL1, XTAL2, RESET)	−0.5	0.6	−0.5	0.6	V	
V_{IH}	Input High Voltage (Except XTAL1, XTAL2, RESET)	2.2	V_{CC}	2.2	V_{CC}	V	
V_{IH1}	Input High Voltage (XTAL1, XTAL2, RESET)	3.8	V_{CC}	3.8	V_{CC}	V	
V_{OL}	Output Low Voltage (D_0-D_7)		0.45		0.45	V	$I_{OL} = 2.0$ mA
V_{OL1}	Output Low Voltage ($P_{10}P_{17}$, $P_{20}P_{27}$, Sync)		0.45		0.45	V	$I_{OL} = 1.6$ mA
V_{OL2}	Output Low Voltage (PROG)		0.45		0.45	V	$I_{OL} = 1.0$ mA
V_{OH}	Output High Voltage (D_0-D_7)	2.4		2.4		V	$I_{OH} = -400\ \mu A$
V_{OH1}	Output High Voltage (All Other Outputs)	2.4		2.4		V	$I_{OH} = -50\ \mu A$
I_{IL}	Input Leakage Current (T_0, T_1, RD, WR, CS, A_0, EA)		±10		±10	μA	$V_{SS} \leq V_{IN} \geq V_{CC}$
I_{OFL}	Output Leakage Current (D_0-D_7, High Z State)		±10		±10	μA	$V_{SS} + 0.45 \leq V_{OUT} \leq V_{CC}$
I_{LI}	Low Input Load Current ($P_{10}P_{17}$, $P_{20}P_{27}$)		0.5		0.5	mA	$V_{IL} = 0.8V$
I_{LI1}	Low Input Load Current (RESET, SS)		0.2		0.2	mA	$V_{IL} = 0.8V$
I_{DD}	V_{DD} Supply Current		15		15	mA	Typical = 5 mA
$I_{CC} + I_{DD}$	Total Supply Current		125		125	mA	Typical = 60 mA
I_{IH}	Input Leakage Current		100		100	μA	$V_{IN} = V_{CC}$
C_{IN}	Input Capacitance		10		10	pF	
$C_{I/O}$	I/O Capacitance		20		20	pF	

D.C. CHARACTERISTICS—PROGRAMMING ($T_A = 25°C \pm 5°C$, $V_{CC} = 5V \pm 5\%$, $V_{DD} = 20V \pm .5V$)

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
V_{DDH}	V_{DD} Program Voltage High Level	19.5	20.5	V	
V_{DDL}	V_{DD} Voltage Low Level	4.75	5.25	V	
V_{PH}	PROG Program Voltage High Level	17.5	18.5	V	
V_{PL}	PROG Voltage Low Level		0.2	V	
V_{EAH}	EA Program or Verify Voltage High Level	17.5	18.5	V	
V_{EAL}	EA Voltage Low Level		5.25	V	
I_{DD}	V_{DD} High Voltage Supply Current		30.0	mA	
I_{PROG}	PROG High Voltage Supply Current		16.0	mA	
I_{EA}	EA High Voltage Supply Current		1.0	mA	

A.C. CHARACTERISTICS ($T_A = 0°C$ to $+70°C$, $V_{SS} = 0V$, $V_{CC} = V_{DD} = +5V \pm 10\%$)

DBB READ

Symbol	Parameter	8042 Min.	8042 Max.	8642/8742 Min.	8642/8742 Max.	Units
t_{AR}	CS, A_0 Setup to RD↓	0		0		ns
t_{RA}	CS, A_0 Hold After RD↑	0		0		ns
t_{RR}	RD Pulse Width	160		160		ns
t_{AD}	CS, A_0 to Data Out Delay		130		130	ns[1]
t_{RD}	RD↓ to Data Out Delay		130		130	ns[1]
t_{DF}	RD↑ to Data Float Delay		85		85	ns
t_{CY}	Cycle Time	1.25	15	1.25	15	μs[2]

DBB WRITE

Symbol	Parameter	Min.	Max.	Min.	Max.	Units
t_{AW}	CS, A_0 Setup to WR↓	0		0		ns
t_{WA}	CS, A_0 Hold After WR↑	0		0		ns
t_{WW}	WR Pulse Width	160		160		ns
t_{DW}	Data Setup to WR↑	130		130		ns
t_{WD}	Data Hold After WR↑	0		0		ns

NOTES:
1. $C_L = 100$ pF.
2. 12 MHz XTAL.

A.C. CHARACTERISTICS—PROGRAMMING ($T_A = 25°C \pm 5°C$, $V_{CC} = 5V \pm 5\%$, $V_{DD} = 20V \pm .5V$)

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	Address Setup Time to $\overline{RESET}$ ↑	$4t_{CY}$			
t_{WA}	Address Hold Time After $\overline{RESET}$ ↑	$4t_{CY}$			
t_{DW}	Data in Setup Time to PROG ↑	$4t_{CY}$			
t_{WD}	Data in Hold Time After PROG ↓	$4t_{CY}$			
t_{PH}	$\overline{RESET}$ Hold Time to Verify	$4t_{CY}$			
t_{VDDW}	V_{DD} Setup Time to PROG ↑	$4t_{CY}$			
t_{VDDH}	V_{DD} Hold Time After PROG ↓	0			
t_{PW}	Program Pulse Width	50	60	mS	
t_{TW}	Test 0 Setup Time for Program Mode	$4t_{CY}$			
t_{WT}	Test 0 Hold Time After Program Mode	$4t_{CY}$			
t_{DO}	Test 0 to Data Out Delay		$4t_{CY}$		
t_{WW}	$\overline{RESET}$ Pulse Width to Latch Address	$4t_{CY}$			
t_r, t_f	V_{DD} and PROG Rise and Fall Times	0.5	2.0	μs	
t_{CY}	CPU Operation Cycle Time	5.0		μs	
t_{RE}	$\overline{RESET}$ Setup Time Before EA ↑.	$4t_{CY}$			

Note: If TEST 0 is high, t_{DO} can be triggered by $\overline{RESET}$ ↑.

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A.C. CHARACTERISTICS DMA

Symbol	Parameter	8042 Min.	8042 Max.	8642/8742 Min.	8642/8742 Max.	Units
t_{ACC}	DACK to WR or RD	0		0		ns
t_{CAC}	RD or WR to DACK	0		0		ns
t_{ACD}	DACK to Data Valid		130		130	ns
t_{CRQ}	RD or WR to DRQ Cleared		100		100	ns[1]

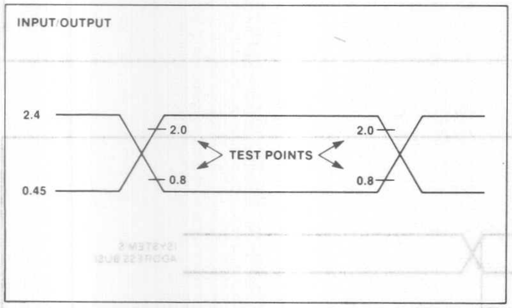
NOTE:
1. $C_L = 150$ pF.

A.C. CHARACTERISTICS PORT 2 ($T_A = 0°C$ to $+70°C$, $V_{CC} = +5V \pm 10\%$)

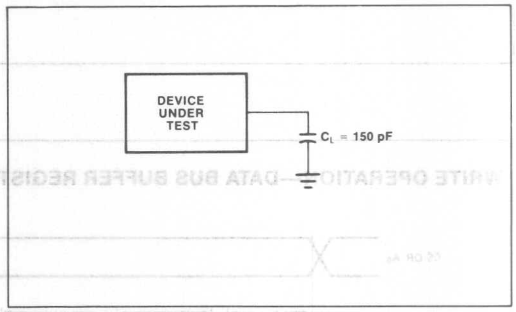
Symbol	Parameter	8042 Min.	8042 Max.	8642/8742 Min.	8642/8742 Max.	Units
t_{CP}	Port Control Setup Before Falling Edge of PROG	80		100		ns[1]
t_{PC}	Port Control Hold After Falling Edge of PROG	60		60		ns[2]
t_{PR}	PROG to Time P2 Input Must Be Valid		650		650	ns[1]
t_{PF}	Input Data Hold Time	0	150	0	150	ns[2]
t_{DP}	Output Data Setup Time	200		200		ns[1]
t_{PD}	Output Data Hold Time	60		60		ns[2]
t_{PP}	PROG Pulse Width	700		700		ns

NOTES:
1. $C_L = 80$ pF.
2. $C_L = 20$ pF.

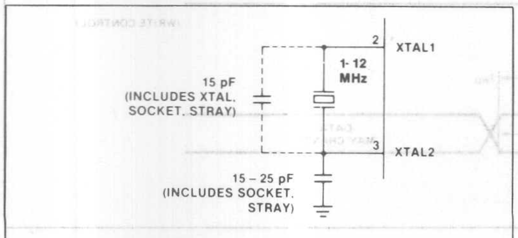
A.C. TESTING INPUT, OUTPUT WAVEFORM



A.C. TESTING LOAD CIRCUIT

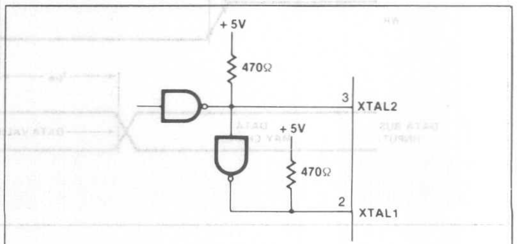


CRYSTAL OSCILLATOR MODE



CRYSTAL SERIES RESISTANCE SHOULD BE <75Ω AT 12 MHz; <180Ω AT 3.6 MHz.

DRIVING FROM EXTERNAL SOURCE



BOTH XTAL1 AND XTAL2 SHOULD BE DRIVEN. RESISTORS TO V_{CC} ARE NEEDED TO ENSURE $V_{IH} = 3.8V$ IF TTL CIRCUITRY IS USED.

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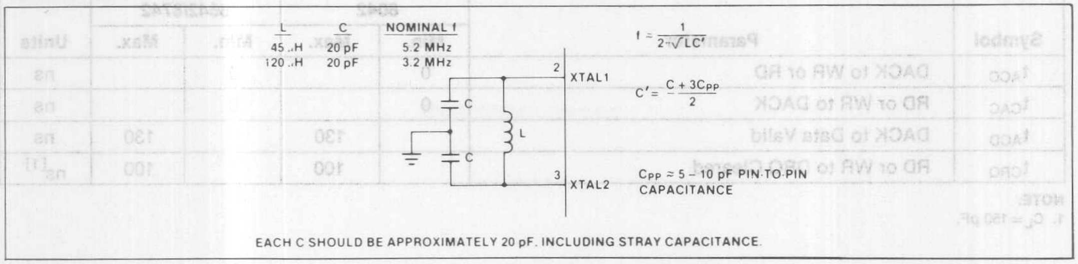
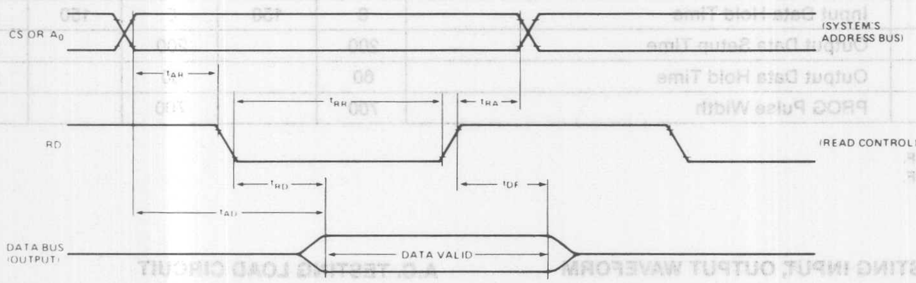
LC OSCILLATOR MODE

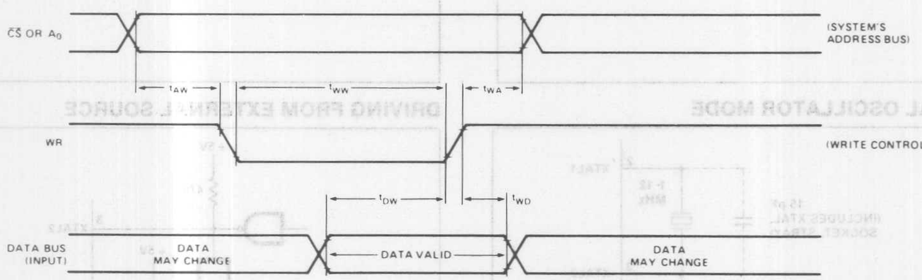


WAVEFORMS

READ OPERATION—DATA BUS BUFFER REGISTER

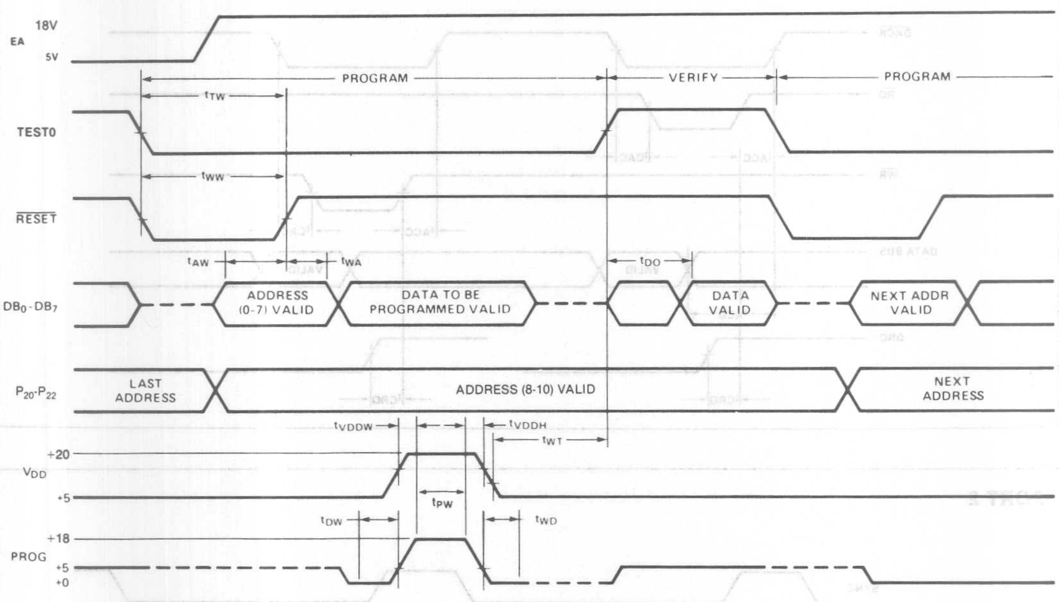


WRITE OPERATION—DATA BUS BUFFER REGISTER

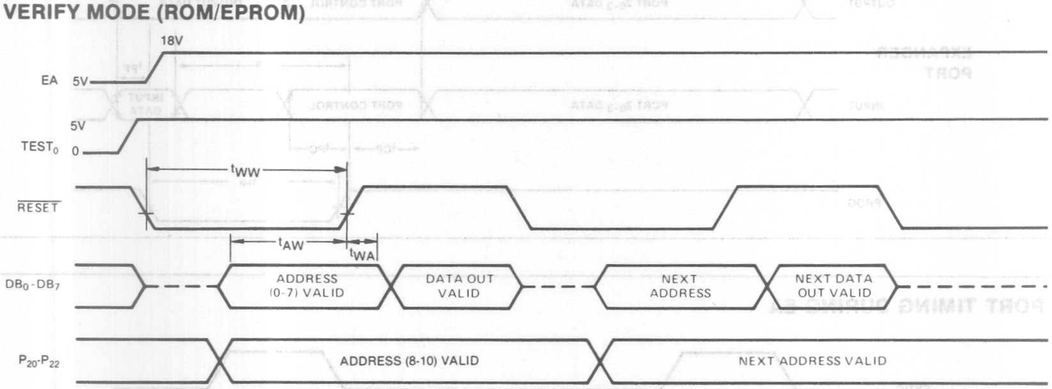


WAVEFORMS (Continued)

COMBINATION PROGRAM/VERIFY MODE (EPROM'S ONLY)



VERIFY MODE (ROM/EPROM)



NOTES:
1. PROG MUST FLOAT IF EA IS LOW (i.e., ≠ 21V) OR IF $TEST_0$ = 5V FOR THE 8742. FOR THE 8042 PROG MUST ALWAYS FLOAT.
2. A_0 MUST BE HELD LOW (i.e., = 0V) DURING PROGRAM/VERIFY MODES.
3. TEST 0 MUST BE HELD HIGH.

The 8742 EPROM can be programmed by the following Intel product:

1. Universal PROM Programmer (UPP series) peripheral of the Intellec® Development System with a UPP-549 Personality Card.

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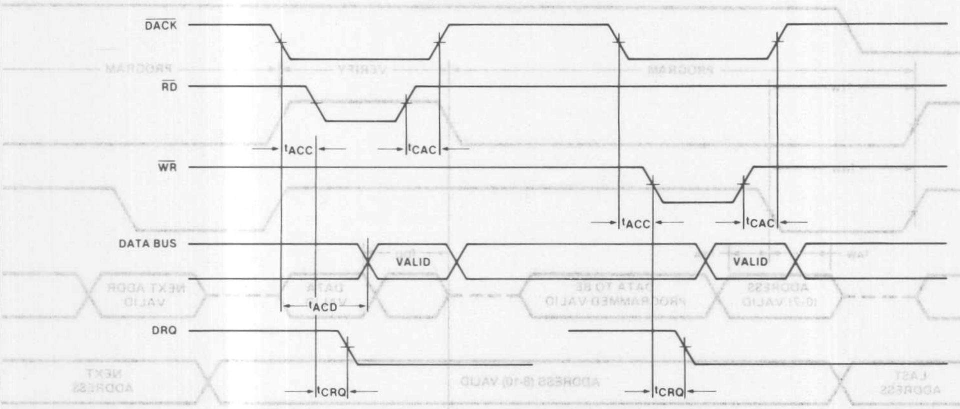
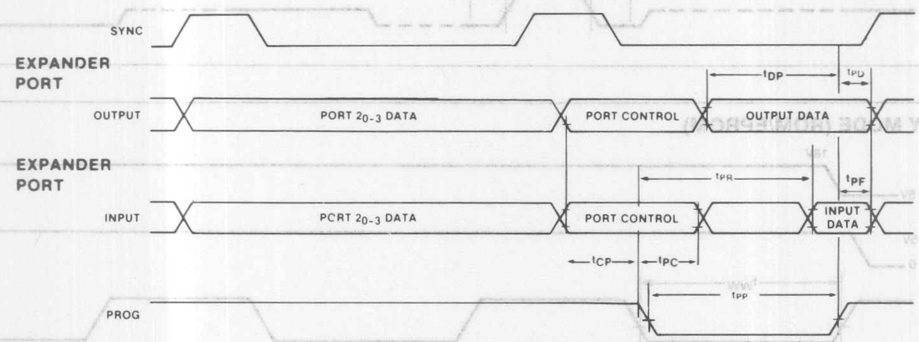
WAVEFORMS (Continued)

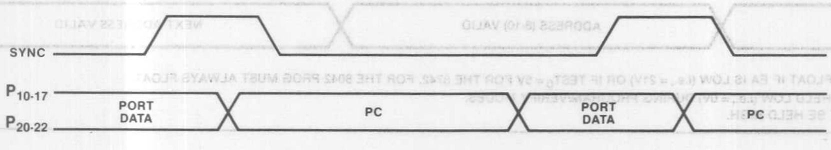
DMA



PORT 2



PORT TIMING DURING EA



ON THE RISING EDGE OF SYNC AND EA IS ENABLED, PORT DATA IS VALID AND CAN BE STROBED. ON THE TRAILING EDGE OF SYNC THE PROGRAM COUNTER CONTENTS ARE AVAILABLE.

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Table 2. UPI™ Instruction Set

Mnemonic	Description	Bytes	Cycles
ACCUMULATOR			
ADD A, Rr	Add register to A	1	1
ADD A, @Rr	Add data memory to A	1	1
ADD A, #data	Add immediate to A	2	2
ADDC A, Rr	Add register to A with carry	1	1
ADDC A, @Rr	Add data memory to A with carry	1	1
ADDC A, #data	Add immediate to A with carry	2	2
ANL A, Rr	AND register to A	1	1
ANL A, @Rr	AND data memory to A	1	1
ANL A, #data	AND immediate to A	2	2
ORL A, Rr	OR register to A	1	1
ORL A, @Rr	OR data memory to A	1	1
ORL A, #data	OR immediate to A	2	2
XRL A, Rr	Exclusive OR register to A	1	1
XRL A, @Rr	Exclusive OR data memory to A	1	1
XRL A, #data	Exclusive OR immediate to A	2	2
INC A	Increment A	1	1
DEC A	Decrement A	1	1
CLR A	Clear A	1	1
CPL A	Complement A	1	1
DA A	Decimal Adjust A	1	1
SWAP A	Swap nibbles of A	1	1
RL A	Rotate A left	1	1
RLC A	Rotate A left through carry	1	1
RR A	Rotate A right	1	1
RRC A	Rotate A right through carry	1	1
INPUT/OUTPUT			
IN A, Pp	Input port toA	1	2
OUTL Pp, A	Output A to port	1	2
ANL Pp, #data	AND immediate to port	2	2
ORL Pp, #data	OR immediate to port	2	2
IN A, DBB	Input DBB to A, clear IBF	1	1
OUT DBB, A	Output A to DBB, set OBF	1	1
MOV STS, A	A_4–A_7 to Bits 4–7 of Status	1	1
MOVD A, Pp	Input Expander port to A	1	2
MOVD Pp, A	Output A to Expander port	1	2
ANLD Pp, A	AND A to Expander port	1	2
ORLD Pp, A	OR A to Expander port	1	2

Mnemonic	Description	Bytes	Cycles
DATA MOVES			
MOV A, Rr	Move register to A	1	1
MOV A, @Rr	Move data memory to A	1	1
MOV A, #data	Move immediate TO A	2	2
MOV Rr, A	Move A to register	1	1
MOV @Rr, A	Move A to data memory	1	1
MOV Rr, #data	Move immediate to register	2	2
MOV @Rr, #data	Move immediate to data memory	2	2
MOV A, PSW	Move PSW to A	1	1
MOV PSW, A	Move A to PSW	1	1
XCH A, Rr	Exchange A and register	1	1
XCH A, @Rr	Exchange A and data memory	1	1
XCHD A, @Rr	Exchange digit of A and register	1	1
MOVP A, @A	Move to A from current page	1	2
MOVP3, A, @A	Move to A from page 3	1	2
TIMER/COUNTER			
MOV A, T	Read Timer/Counter	1	1
MOV T, A	Load Timer/Counter	1	1
STRT T	Start Timer	1	1
STRT CNT	start Counter	1	1
STOP TCNT	Stop Timer/Counter	1	1
EN TCNTI	Enable Timer/ Counter Interrupt	1	1
DIS TCNTI	Disable Timer/ Counter Interrupt	1	1
CONTROL			
EN DMA	Enable DMA Handshake Lines	1	1
EN I	Enable IBF Interrupt	1	1
DIS I	Disable IBF Interrupt	1	1
EN FLAGS	Enable Master Interrupts	1	1
SEL RB0	Select register bank 0	1	1
SEL RB1	Select register bank 1	1	1
NOP	No Operation	1	1
REGISTERS			
INC Rr	Increment register	1	1
INC @Rr	Increment data memory	1	1
DEC Rr	Decrement register	1	1
SUBROUTINE			
CALL addr	Jump to subroutine	2	2
RET	Return	1	2
RETR	Return and restore status	1	2

Table 2. UPI™ Instruction Set (Continued)

Mnemonic	Description	Bytes	Cycles
FLAGS			
CLR C	Clear Carry	1	1
CPL C	Complement Carry	1	1
CLR F0	Clear Flag 0	1	1
CPL F0	Complement Flag 0	1	1
CLR F1	Clear F1 Flag	1	1
CPL F1	Complement F1 Flag	1	1
BRANCH			
JMP addr	Jump unconditional	2	2
JMPP @A	Jump indirect	1	2
DJNZ Rr, addr	Decrement register and jump	2	2
JC addr	Jump on Carry=1	2	2
JNC addr	Jump on Carry=0	2	2
JZ addr	Jump on A Zero	2	2
JNZ addr	Jump on A not Zero	2	2
JT0 addr	Jump on T0=1	2	2
JNT0 addr	Jump on T0=0	2	2
JT1 addr	Jump on T1=1	2	2
JNT1 addr	Jump on T1=0	2	2
JF0 addr	Jump on F0 Flag=1	2	2
JF1 addr	Jump on F1 Flag=1	2	2
JTF addr	Jump on Timer Flag =1, Clear Flag	2	2
JNIBF addr	Jump on IBF Flag =0	2	2
JOBF addr	Jump on OBF Flag =1	2	2
JBb addr	Jump on Accumulator Bit	2	2

AFN-01832A

8243
MCS-48® INPUT/OUTPUT EXPANDER

- Low Cost
- Simple Interface to MCS-48® Microcomputers
- Four 4-Bit I/O Ports
- AND and OR Directly to Ports
- 24-Pin DIP
- Single 5V Supply
- High Output Drive
- Direct Extension of Resident 8048 I/O Ports

The Intel® 8243 is an input/output expander designed specifically to provide a low cost means of I/O expansion for the MCS-48® family of single chip microcomputers. Fabricated in 5 volts NMOS, the 8243 combines low cost, single supply voltage and high drive current capability.

The 8243 consists of four 4-bit bidirectional static I/O ports and one 4-bit port which serves as an interface to the MCS-48 microcomputers. The 4-bit interface requires that only 4 I/O lines of the 8048 be used for I/O expansion, and also allows multiple 8243's to be added to the same bus.

The I/O ports of the 8243 serve as a direct extension of the resident I/O facilities of the MCS-48 microcomputers and are accessed by their own MOV, ANL, and ORL instructions.

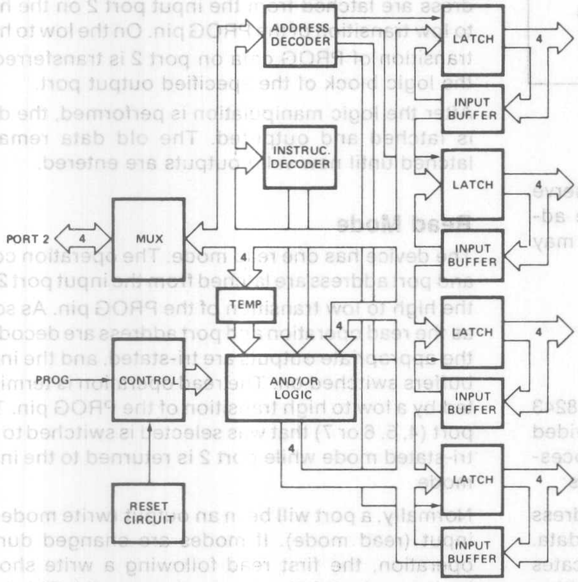


Figure 1. 8243 Block Diagram

Figure 2. 8243 Pin Configuration

AFN-00214A-01

Table 1. Pin Description

Symbol	Pin No.	Function
PROG	7	Clock Input. A high to low transition on PROG signifies that address and control are available on P20-P23, and a low to high transition signifies that data is available on P20-P23.
$\overline{CS}$	6	Chip Select Input. A high on CS inhibits any change of output or internal status.
P20-P23	11-8	Four (4) bit bi-directional port contains the address and control bits on a high to low transition of PROG. During a low to high transition contains the data for a selected output port if a write operation, or the data from a selected port before the low to high transition if a read operation.
GND	12	0 volt supply.
P40-P43 P50-P53 P60-P63 P70-P73	2-5 1, 23-21 20-17 13-16	Four (4) bit bi-directional I/O ports. May be programmed to be input (during read), low impedance latched output (after write), or a tri-state (after read). Data on pins P20-P23 may be directly written, ANDed or ORed with previous data.
V_{CC}	24	+5 volt supply.

FUNCTIONAL DESCRIPTION

General Operation

The 8243 contains four 4-bit I/O ports which serve as an extension of the on-chip I/O and are addressed as ports 4-7. The following operations may be performed on these ports:

- Transfer Accumulator to Port.
- Transfer Port to Accumulator.
- AND Accumulator to Port.
- OR Accumulator to Port.

All communication between the 8048 and the 8243 occurs over Port 2 (P20-P23) with timing provided by an output pulse on the PROG pin of the processor. Each transfer consists of two 4-bit nibbles:

The first containing the "op code" and port address and the second containing the actual 4-bits of data. A high to low transition of the PROG line indicates that address is present while a low to high transition indicates the presence of data. Additional 8243's may be added to the 4-bit bus and chip selected using additional output lines from the 8048/8748/8035.

Power On Initialization

Initial application of power to the device forces input/output ports 4, 5, 6, and 7 to the tri-state and port 2 to the input mode. The PROG pin may be either high or low when power is applied. The first high to low transition of PROG causes device to exit power on mode. The power on sequence is initiated if VCC drops below 1V.

P21	P20	Address Code	P23	P22	Instruction Code
0	0	Port 4	0	0	Read
0	1	Port 5	0	1	Write
1	0	Port 6	1	0	ORLD
1	1	Port 7	1	1	ANLD

Write Modes

The device has three write modes. MOVD Pi, A directly writes new data into the selected port and old data is lost. ORLD Pi, A takes new data, OR's it with the old data and then writes it to the port. ANLD Pi, A takes new data, AND's it with the old data and then writes it to the port. Operation code and port address are latched from the input port 2 on the high to low transition of the PROG pin. On the low to high transition of PROG data on port 2 is transferred to the logic block of the specified output port.

After the logic manipulation is performed, the data is latched and outputed. The old data remains latched until new valid outputs are entered.

Read Mode

The device has one read mode. The operation code and port address are latched from the input port 2 on the high to low transition of the PROG pin. As soon as the read operation and port address are decoded, the appropriate outputs are tri-stated, and the input buffers switched on. The read operation is terminated by a low to high transition of the PROG pin. The port (4, 5, 6 or 7) that was selected is switched to the tri-stated mode while port 2 is returned to the input mode.

Normally, a port will be in an output (write mode) or input (read mode). If modes are changed during operation, the first read following a write should be ignored; all following reads are valid. This is to allow the external driver on the port to settle after the first read instruction removes the low impedance drive from the 8243 output. A read of any port will leave that port in a high impedance state.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias .... 0°C to 70°C
Storage Temperature .... -65°C to +150°C
Voltage on Any Pin
  With Respect to Ground .... -0.5 V to +7V
Power Dissipation .... 1 Watt

**NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

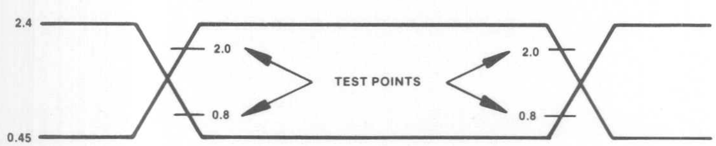
D.C. CHARACTERISTICS T_A = 0°C to 70°C, V_{CC} = 5V 10%

Symbol	Parameter	Min	Typ	Max	Units	Test Conditions
V_{IL}	Input Low Voltage	-0.5		0.8	V	
V_{IH}	Input High Voltage	2.0		V_{CC}+0.5	V	
V_{OL1}	Output Low Voltage Ports 4-7			0.45	V	I_{OL} = 4.5 mA*
V_{OL2}	Output Low Voltage Port 7			1	V	I_{OL} = 20 mA
V_{OH1}	Output High Voltage Ports 4-7	2.4			V	I_{OH} = 240μA
I_{IL1}	Input Leakage Ports 4-7	-10		20	μA	V_{in} = V_{CC} to OV
I_{IL2}	Input Leakage Port 2, CS, PROG	-10		10	μA	V_{in} = V_{CC} to OV
V_{OL3}	Output Low Voltage Port 2			.45	V	I_{OL} = 0.6 mA
I_{CC}	V_{CC} Supply Current		10	20	mA	
V_{OH2}	Output Voltage Port 2	2.4				I_{OH} = 100μA
I_{OL}	Sum of all I_{OL} from 16 Outputs			72	mA	4.5 mA Each Pin

*See following graph for additional sink current capability

A.C. CHARACTERISTICS T_A = 0°C to 70°C, V_{CC} = 5V 10%

Symbol	Parameter	Min	Max	Units	Test Conditions
t_A	Code Valid Before PROG	100		ns	80 pF Load
t_B	Code Valid After PROG	60		ns	20 pF Load
t_C	Data Valid Before PROG	200		ns	80 pF Load
t_D	Data Valid After PROG	20		ns	20 pF Load
t_H	Floating After PROG	0	150	ns	20 pF Load
t_K	PROG Negative Pulse Width	700		ns	
t_{CS}	CS Valid Before/After PROG	50		ns	
t_{PO}	Ports 4-7 Valid After PROG		700	ns	100 pF Load
t_{LP1}	Ports 4-7 Valid Before/After PROG	100		ns	
t_{ACC}	Port 2 Valid After PROG		650	ns	80 pF Load



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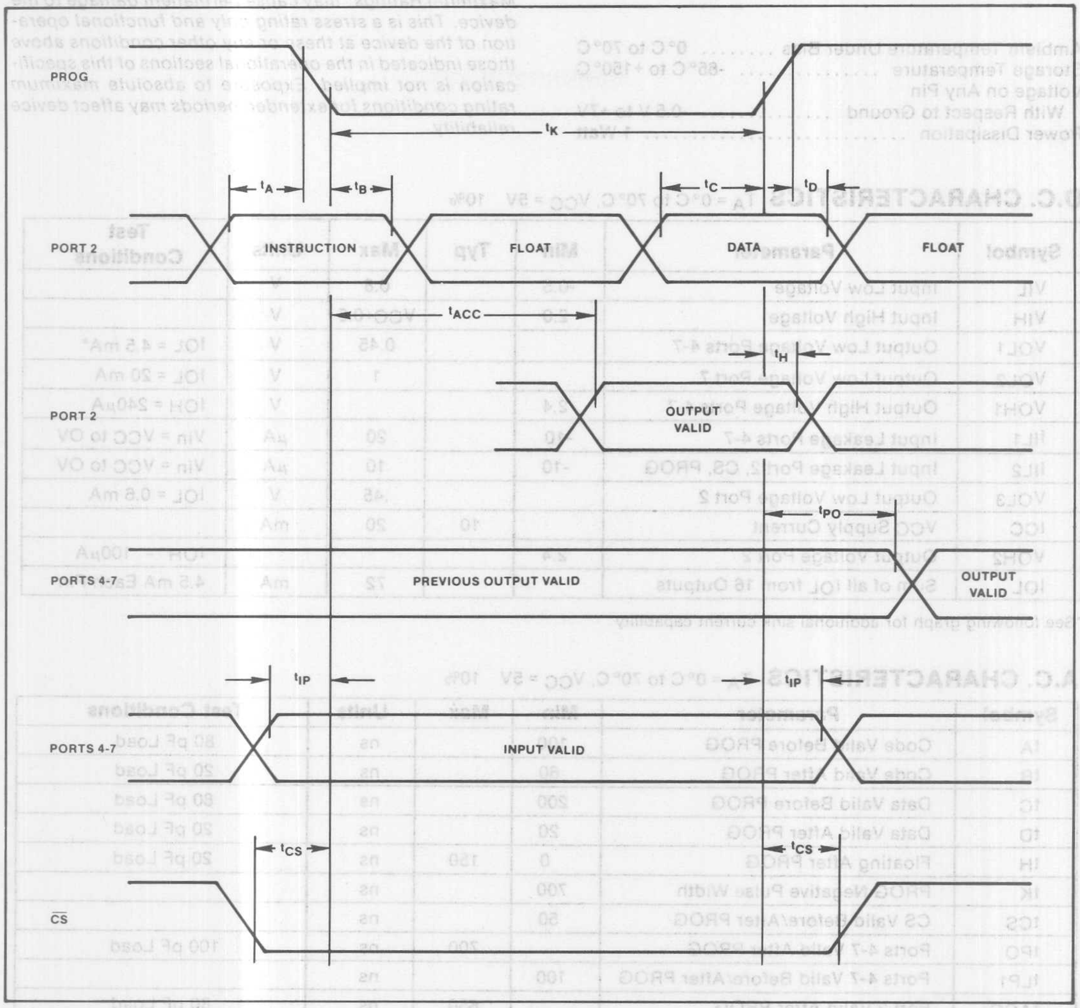
WAVEFORMS



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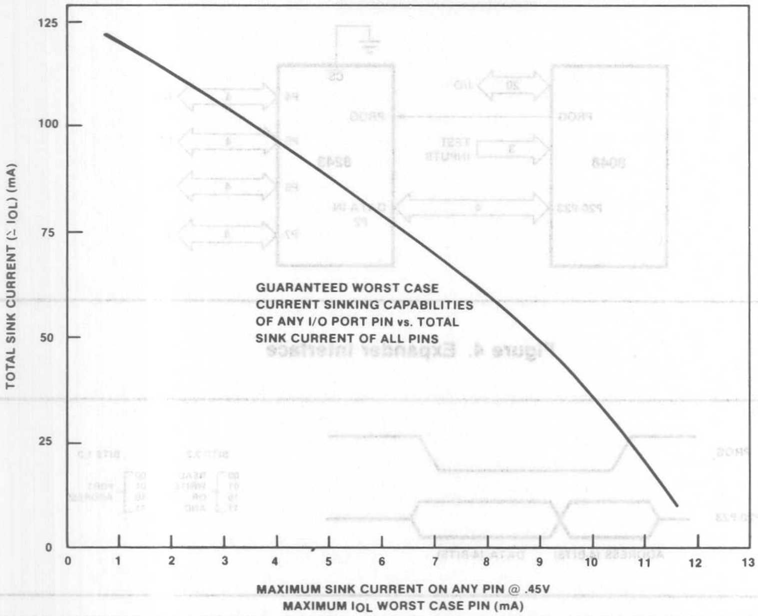

Figure 3

Sink Capability

The 8243 can sink 5 mA @ .45V on each of its 16 I/O lines simultaneously. If, however, all lines are not sinking simultaneously or all lines are not fully loaded, the drive capability of any individual line increases as is shown by the accompanying curve.

For example, if only 5 of the 16 lines are to sink current at one time, the curve shows that each of those 5 lines is capable of sinking 9 mA @ .45V (if any lines are to sink 9 mA the total I_{OL} must not exceed 45 mA or five 9 mA loads).

Example: How many pins can drive 5 TTL loads (1.6 mA) assuming remaining pins are unloaded?

I_{OL} = 5 x 1.6 mA = 8 mA
ϵI_{OL} = 60 mA from curve
pins = 60 mA ÷ 8 mA/pin = 7.5 = 7

In this case, 7 lines can sink 8 mA for a total of 56mA. This leaves 4 mA sink current capability which can be divided in any way among the remaining 8 I/O lines of the 8243.

Example: This example shows how the use of the 20 mA sink capability of Port 7 affects the sinking capability of the other I/O lines.

An 8243 will drive the following loads simultaneously.

2 loads — 20 mA @ 1V (port 7 only)
8 loads — 4 mA @ .45V
6 loads — 3.2 mA @ .45V
Is this within the specified limits?

ϵI_{OL} = (2 x 20) + (8 x 4) + (6 x 3.2) = 91.2 mA.
From the curve: for I_{OL} = 4 mA, $\epsilon I_{OL} \approx$ 93 mA.
since 91.2 mA $<$ 93 mA the loads are within specified limits.

Although the 20 mA @ 1V loads are used in calculating ϵI_{OL}, it is the largest current required @ .45V which determines the maximum allowable ϵI_{OL}.

NOTE: A10 to 50K Ω pullup resistor to +5V should be added to 8243 outputs when driving to 5V CMOS directly.

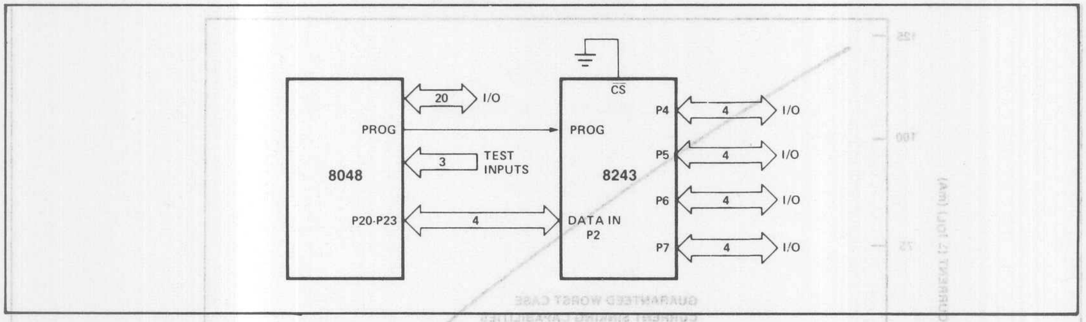

Figure 4. Expander Interface

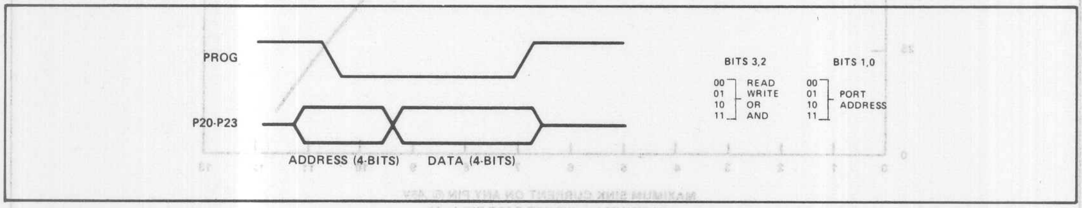

Figure 5. Output Expander Timing

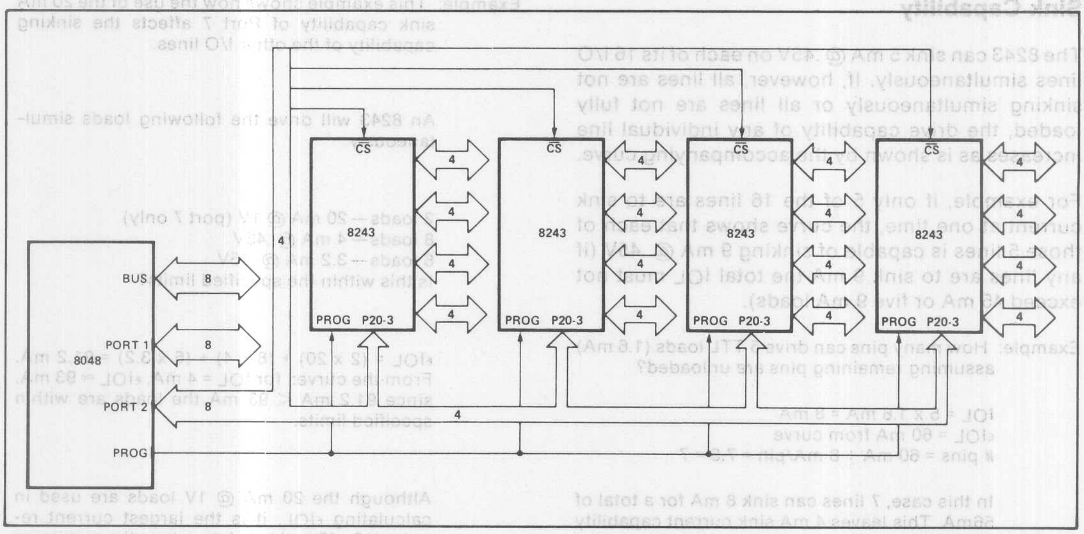

Figure 6. Using Multiple 8243's

intel®

8292 GPIB CONTROLLER

- **Complete IEEE Standard 488 Controller Function**
- **Interface Clear (IFC) Sending Capability Allows Seizure of Bus Control and/or Initialization of the Bus**
- **Responds to Service Requests (SRQ)**
- **Sends Remote Enable (REN), Allowing Instruments to Switch to Remote Control**
- **Complete Implementation of Transfer Control Protocol**
- **Synchronous Control Seizure Prevents the Destruction of Any Data Transmission in Progress**
- **Connects with the 8291 to Form a Complete IEEE Standard 488 Interface Talker/Listener/Controller**

The 8292 GPIB Controller is a microprocessor-controlled chip designed to function with the 8291 GPIB Talker/Listener to implement the full IEEE Standard 488 controller function, including transfer control protocol. The 8292 is a pre-programmed Intel® 8041A.

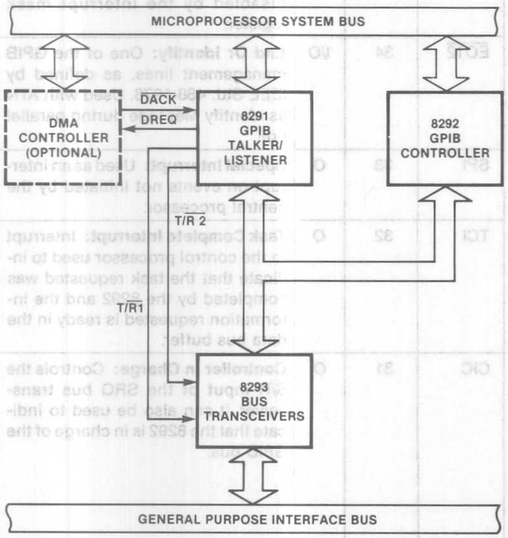

Figure 1. 8291, 8292 Block Diagram

Figure 2. Pin Configuration

Table 1. Pin Description

Symbol	Pin No.	Type	Name and Function
$\overline{IFCL}$	1	I	**IFC Received (Latched):** The 8292 monitors the IFC Line (when not system controller) through this pin.
X_1, X_2	2, 3	I	**Crystal Inputs:** Inputs for a crystal, LC or an external timing signal to determine the internal oscillator frequency.
RESET	4	I	**Reset:** Used to initialize the chip to a known state during power on.
$\overline{CS}$	6	I	**Chip Select Input:** Used to select the 8292 from other devices on the common data bus.
$\overline{RD}$	8	I	**Read Enable:** Allows the master CPU to read from the 8292.
A_0	9	I	**Address Line:** Used to select between the data bus and the status register during read operations and to distinguish between data and commands written into the 8292 during write operations.
$\overline{WR}$	10	I	**Write Enable:** Allows the master CPU to write to the 8292.
SYNC	11	O	**Sync:** 8041A instruction cycle synchronization signal; it is an output clock with a frequency of XTAL ÷ 15.
D_0–D_7	12-19	I/O	**Data:** 8 bidirectional lines used for communication between the central processor and the 8292's data bus buffers and status register.
V_{SS}	7, 20	P.S.	**Ground:** Circuit ground potential.
$\overline{SRQ}$	21	I	**Service Request:** One of the IEEE control lines. Sampled by the 8292 when it is controller in charge. If true, SPI interrupt to the master will be generated.
$\overline{ATNI}$	22	I	**Attention In:** Used by the 8292 to monitor the GPIB ATN control line. It is used during the transfer control procedure.
$\overline{IFC}$	23	I/O	**Interface Clear:** One of the GPIB management lines, as defined by IEEE Std. 488-1978, places all devices in a known quiescent state.
SYC	24	I	**System Conroller:** Monitors the system controller switch.
CLTH	27	O	**Clear Latch:** Used to clear the $\overline{IFCR}$ latch after being recognized by the 8292. Usually low (except after hardware Reset), it will be pulsed high when IFCR is recognized by the 8292.
$\overline{ATNO}$	29	O	**Attention Out:** Controls the ATN control line of the bus through external logic for tcs and tca procedures. (ATN is a GPIB control line, as defined by IEEE Std. 488-1978.)
V_{CC}	5, 26, 40	P.S.	**Voltage:** +5V supply input ±10%.
COUNT	39	I	**Event Count:** When enabled by the proper command the internal counter will count external events through this pin. High to low transition will increment the internal counter by one. The pin is sampled once per three internal instruction cycles (7.5μsec sample period when using 5 MHz XTAL). It can be used for byte counting when connected to NDAC, or for block counting when connected to the EOI.
$\overline{REN}$	38	O	**Remote Enable:** The Remote Enable bus signal selects remote or local control of the device on the bus. A GPIB bus management line, as defined by IEEE Std. 488-1978.
$\overline{DAV}$	37	I/O	**Data Valid:** Used during parallel poll to force the 8291 to accept the parallel poll status bits. It is also used during the tcs procedure.
$\overline{IBFI}$	36	O	**Input Buffer Not Full:** Used to interrupt the central processor while the input buffer of the 8292 is empty. This feature is enabled and disabled by the interrupt mask register.
OBFI	35	O	**Output Buffer Full:** Used as an interrupt to the central processor while the output buffer of the 8292 is full. The feature can be enabled and disabled by the interrupt mask register.
$\overline{EO12}$	34	I/O	**End Or Identify:** One of the GPIB management lines, as defined by IEEE Std. 488-1978. Used with ATN as Identify Message during parallel poll.
SPI	33	O	**Special Interrupt:** Used as an interrupt on events not initiated by the central processor.
TCI	32	O	**Task Complete Interrupt:** Interrupt to the control processor used to indicate that the task requested was completed by the 8292 and the information requested is ready in the data bus buffer.
CIC	31	O	**Controller In Charge:** Controls the S/R input of the SRQ bus transceiver. It can also be used to indicate that the 8292 is in charge of the GPIB bus.

FUNCTIONAL DESCRIPTION

The 8292 is an Intel 8041A which has been programmed as a GPIB Controller interface element. It is used with the 8291 GPIB Talker/Listener and two 8293 GPIB Transceivers to form a complete IEEE-488 Bus Interface for a microprocessor. The electrical interface is performed by the transceivers, data transfer is done by the talker/listener, and control of the bus is done by the 8292. Figure 3 is a typical controller interface using Intel's GPIB peripherals.

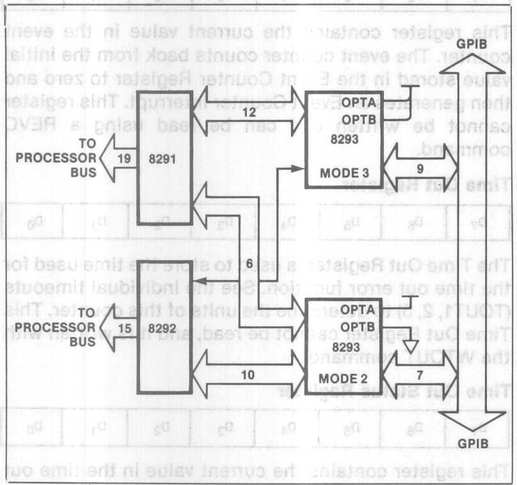

Figure 3. Talker/Listener/Controller Configuration

The internal RAM in the 8041A is used as a special purpose register bank for the 8292. Most of these registers (except for the interrupt flag) can be accessed through commands to the 8292. Table 2 identifies the registers used by the 8292 and how they are accessed.

Interrupt Status Register

D_7							D_0
SYC	ERR	SRQ	EV	X	IFCR	IBF	OBF

The 8292 can be configured to interrupt the microprocessor on one of several conditions. Upon receipt of the interrupt the microprocessor must read the 8292 interrupt status register to determine which event caused the interrupt, and then the appropriate subroutine can be performed. The interrupt status register is read with A_0 high. With the exception of OBF and IBF, these interrupts are enabled or disabled by the SPI interrupt mask. OBF and IBF have their own bits in the interrupt mask (OBFI and IBFI).

OBF Output Buffer Full. A byte is waiting to be read by the microprocessor. This flag is cleared when the output data bus buffer is read.

IBF Input Buffer Full. The byte previously written by the microprocessor has not been read yet by the 8292. If another byte is written to the 8292 before this flag clears, data will be lost. IBF is cleared when the 8292 reads the data byte.

IFCR Interface Clear Received. The GPIB system controller has set IFC. The 8292 has become idle and is no longer in charge of the bus. The flag is cleared when the IACK command is issued.

EV Event Counter Interrupt. The requested number of blocks or data bytes has been transferred. The EV interrupt flag is cleared by the IACK command.

SRQ Service Request. Notifies the 8292 that a service request (SRQ) message has been received. It is cleared by the IACK command.

ERR Error occurred. The type of error can be determined by reading the error status register. This interrupt flag is cleared by the IACK command.

SYC System Controller Switch Change. Notifies the processor that the state of the system controller switch has changed. The actual state is contained in the GPIB Status Register. This flag is cleared by the IACK command.

Table 2. 8292 Registers

READ FROM 8292

Register	D_7							D_0	A_0
INTERRUPT STATUS	SYC	ERR	SRQ	EV	X	IFCR	IBF	OBF	1
ERROR FLAG	X	X	USER	X	X	$TOUT_3$	$TOUT_2$	$TOUT_1$	0*
CONTROLLER STATUS	CSBS	CA	X	X	SYCS	IFC	REN	SRQ	0*
GPIB (BUS) STATUS	REN	DAV	EOI	X	SYC	IFC	ANTI	SRQ	0*
EVENT COUNTER STATUS	D	D	D	D	D	D	D	D	0*
TIME OUT STATUS	D	D	D	D	D	D	D	D	0*

WRITE TO 8292

Register	D_7							D_0	A_0
INTERRUPT MASK	1	SPI	TCI	SYC	OBFI	IBFI	0	SRQ	0
ERROR MASK	0	0	USER	0	0	$TOUT_3$	$TOUT_2$	$TOUT_1$	0
COMMAND FIELD	1	1	1	OP	C	C	C	C	1
EVENT COUNTER	D	D	D	D	D	D	D	D	0*
TIME OUT	D	D	D	D	D	D	D	D	0*

Note: These registers are accessed by a special utility command, see page 6.

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Interrupt Mask Register

1	SPI	TCI	SYC	OBFI	$\overline{IBFI}$	0	SRQ

D_7 ... D_0

The Interrupt Mask Register is used to enable features and to mask the SPI and TCI interrupts. The flags in the Interrupt Status Register will be active even when masked out. The Interrupt Mask Register is written when A_0 is low and reset by the RINM command. When the register is read, D_1 and D_7 are undefined. An intertupt is enabled by setting the corresponding register bit.

SRQ Enable interrupts on SRQ received.

$\overline{IBFI}$ Enable interrupts on input buffer empty.

OBFI Enable interrupts on output buffer full.

SYC Enable interrupts on a change in the system controller switch.

TCI Enable interrupts on the task completed.

SPI Enable interrupts on special events.

NOTE: The event counter is enabled by the GSEC command, the error interrupt is enabled by the error mask register, and IFC cannot be masked (it will always cause an interrupt).

Controller Status Register

CSBS	CA	X	X	SYCS	IFC	REN	SRQ

D_7 ... D_0

The Controller Status Register is used to determine the status of the controller function. This register is accessed by the RCST command.

SRQ Service Request line active (CSRS).

REN Sending Remote Enable.

IFC Sending or receiving interface clear.

SYCS System Controller Switch Status (SACS).

CA Controller Active (CACS + CAWS + CSWS).

CSBS Controller Stand-by State (CSBS, CA) = (0,0) — Controller Idle

GPIB Bus Status Register

REN	DAV	EOI	X	SYC	IFC	ATNI	SRQ

D_7 ... D_0

This register contains GPIB bus status information. It can be used by the microprocessor to monitor and manage the bus. The GPIB Bus Register can be read using the RBST command.

Each of these status bits reflect the current status of the corresponding pin on the 8292.

SRQ Service Request

ATNI Attention In

IFC Interface Clear

SYC System Controller Switch

EOI End or Identify

DAV Data Valid

REN Remote Enable

Event Counter Register

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

The Event Counter Register contains the initial value for the event counter. The counter can count pulses on pin 39 of the 8292 (COUNT). It can be connected to EOI or NDAC to count blocks or bytes respectively during standby state. A count of zero equals 256. This register cannot be read, and is written using the WEVC command.

Event Counter Status Register

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

This register contains the current value in the event counter. The event counter counts back from the initial value stored in the Event Counter Register to zero and then generates an Event Counter Interrupt. This register cannot be written and can be read using a REVC command.

Time Out Register

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

The Time Out Register is used to store the time used for the time out error function. See the individual timeouts (TOUT1, 2, 3) to determine the units of this counter. This Time Out Register cannot be read, and it is written with the WTOUT command.

Time Out Status Register

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0

This register contains the current value in the time out counter. The time out counter decrements from the original value stored in the Time Out Register. When zero is reached, the appropriate error interrupt is generated. If the register is read while none of the time out functions are active, the register will contain the last value reached the last time a function was active. The Time Out Status Register cannot be written, and it is read with the RTOUT command.

Error Flag Register

X	X	USER	X	X	$TOUT_3$	$TOUT_2$	$TOUT_1$

D_7 ... D_0

Four errors are flagged by the 8292 with a bit in the Error Flag Register. Each of these errors can be masked by the Error Mask Register. The Error Flag Register cannot be written, and it is read by the IACK command when the error flag in the Interrupt Status Register is set.

TOUT1 Time Out Error 1 occurs when the current controller has not stopped sending ATN after receiving the TCT message for the time period specified by the Time Out Register. Each count in the Time Out Register is at least 1800 t_{CY}. After flagging the error, the 8292 will remain in a loop trying to take control until the current controller stops sending ATN or a new command is written by the microprocessor. If a new command is written, the 8292 will return to the loop after executing it.

TOUT2 Time Out Error 2 occurs when the transmission between the addressed talker and listener has not started for the time period specified by the Time Out Register. Each count in the Time Out Register is at least 45 t_{CY}. This feature is only enabled when the controller is in the CSBS state.

TOUT3 Time Out Error 3 occurs when the handshake signals are stuck and the 8292 is not succeeding in taking control synchronously for the time period specified by the Time Out Register. Each count in the Time Out Register is at least 1800 t_{CY}. The 8292 will continue checking $\overline{ATNI}$ until it becomes true or a new command is received. After performing the new command, the 8292 will return to the $\overline{ATNI}$ checking loop.

USER User error occurs when request to assert IFC or REN was received and the 8292 was not the system controller.

Error Mask Register

D_7							D_0
0	0	USER	0	0	$TOUT_3$	$TOUT_2$	$TOUT_1$

The Error Mask Register is used to mask the interrupt from a particular type of error. Each type of error interrupt is enabled by setting the corresponding bit in the Error Mask Register. This register can be read with the RERM command and written with A_0 low.

Command Register

D_7							D_0
1	1	1	OP	C	C	C	C

Commands are performed by the 8292 whenever a byte is written with A_0 high. There are two categories of commands distinguished by the OP bit (bit 4). The first category is the operation command (OP = 1). These commands initiate some action on the interface bus. The second category is the utility commands (OP = 0). These commands are used to aid the communication between the processor and the 8292.

OPERATION COMMANDS

Operation commands initiate some action on the GPIB interface bus. It is using these commands that the control functions such as polling, taking and passing control, and system controller functions are performed. A TCI interrupt is generated upon successful completion of each of these functions.

F0 — SPCNI — Stop Counter Interrupts

This command disables the internal counter interrupt so that the 8292 will stop interrupting the master on event counter underflows. However, the counter will continue counting and its contents can still be used.

F1 — GIDL — Go To Idle

This command is used during the transfer of control procedure while transferring control to another controller. The 8292 will respond to this command only if it is in the active state. $\overline{ATNO}$ will go high, and $\overline{CIC}$ will be high so that this 8292 will no longer be driving the ATN line on the GPIB interface bus.

F2 — RST — Reset

This command has the same effect as asserting the external reset on the 8292. For details, refer to the reset procedure described later.

F3 — RSTI — Reset Interrupts

This command resets any pending interrupts and clears the error flags. The 8292 will not return to any loop it was in (such as from the time out interrupts).

F4 — GSEC — Go To Standby, Enable Counting

The function causes $\overline{ATNO}$ to go high and the counter will be enabled. If the 8292 was not the active controller, this command will exit immediately. If the 8292 is the active controller, the counter will be loaded with the value stored in the Event Counter Register, and the internal interrupt will be enabled so that when the counter reaches zero, the SPI interrupt will be generated. SPI will be generated every 256 counts thereafter until the controller exits the standby state or the SPCNI command is written. An initial count of 256 (zero in the Event Counter Register) will be used if the WEVC command is not executed. If the data transmission does not start, a TOUT2 error will be generated.

F5 — EXPP — Execute Parallel Poll

This command initiates a parallel poll by asserting ATN and EOI (IDY message) true. The 8291 should be previously configured as a listener. Upon detection of DAV true, the 8291 enters ACDS and latches the parallel poll response (PPR) byte into its data in register. The master will be interrupted by the 8291 BI interrupt when the PPR byte is available. No interrupts except the $\overline{IBFI}$ will be generated by the 8292. The 8292 will respond to this command only when it is the active controller.

F6 — GTSB — Go To Standby

If the 8292 is the active controller, $\overline{ATNO}$ will go high then TCI will be generated. If the data transmission does not start, a TOUT2 error will be generated.

F7 — SLOC — Set Local Mode

If the 8292 is the system controller, then REN will be asserted false for at least 100 μsec. If it is not the system controller, the User Error bit will be set in the Error Flag Register.

F8 — SREM — Set Interface To Remote Control

This command will set REN true if this 8292 is the system controller. If not, the User Error bit will be set in the Error Flag Register.

This command will cause IFC to be asserted true for at least 100 μsec if this 8292 is the system controller. If it is in CIDS, it will take control over the bus (see the TCNTR command).

FA — TCNTR — Take Control

The transfer of control procedure is coordinated by the master with the 8291 and 8292. When the master receives a TCT message from the 8291, it should issue the TCNTR command to the 8292. The following events occur to take control:

1. The 8292 checks to see if it is in CIDS, and if not, it exits.
2. Then $\overline{\text{ATNI}}$ is checked until it becomes high. If the current controller does not release ATN for the time specified by the Time Out Register, then a TOUT1 error is generated. The 8292 will return to this loop after an error or any command except the RST and RSTI commands.
3. After the current controller releases ATN, the 8292 will assert $\overline{\text{ATNO}}$ and $\overline{\text{CIC}}$ low.
4. Finally, the TCI interrupt is generated to inform the master that it is in control of the bus.

FC — TCASY — Take Control Asynchronously

TCAS transfers the 8292 from CSBS to CACS independent of the handshake lines. If a bus hangup is detected (by an error flag), this command will force the 8292 to take control (asserting ATN) even if the AH function is not in ANRS (Acceptor Not Ready State). This command should be used very carefully since it may cause the loss of a data byte. Normally, control should be taken synchronously. After checking the controller function for being in the CSBS (else it will exit immediately), $\overline{\text{ATNO}}$ will go low, and a TCI interrupt will be generated.

FD — TCSY — Take Control Synchronously

There are two different procedures used to transfer the 8292 from CSBS to CACS depending on the state of the 8291 in the system. If the 8291 is in "continuous AH cycling" mode (Aux. Reg. A0 = A1 = 1), then the following procedure should be followed:

1. The master microprocessor stops the continuous AH cycling mode in the 8291;
2. The master reads the 8291 Interrupt Status 1 Register;
3. If the END bit is set, the master sends the TCSY command to the 8292;
4. If the END bit was not set, the master reads the 8291 Data In Register and then waits for another BI interrupt from the 8291. When it occurs, the master sends the 8292 the TCSY command.

If the 8291 is not in AH cycling mode, then the master just waits for a BI interrupt and then sends the TCSY command. After the TCSY command has been issued, the 8292 checks for $\overline{\text{CSBS}}$. If $\overline{\text{CSBS}}$, then it exits the routine. Otherwise, it then checks the DAV bit in the GPIB status. When DAV becomes false, the 8292 will low. If DAV does not go low, a TOUT3 error will be generated.

FE — STCNI — Start Counter Interrupts

This command enables the internal counter interrupt. The counter is enabled by the GSEC command.

UTILITY COMMANDS

All these commands are either Read or Write to registers in the 8292. Upon completion of Read commands, the TCI (Task Completed Interrupt) will be generated. Note that writing to the Error Mask Register and the Interrupt Mask Register are done directly.

E1 — WTOUT — Write To Time Out Register

The byte written to the data bus buffer (with $A_0 = 0$) following this command will determine the time used for the time out function. Since this function is implemented in software, this will not be an accurate time measurement. This feature is enable or disable by the Error Mask Register. No interrupts except for the $\overline{\text{IBFI}}$ will be generated upon completion.

E2 — WEVC — Write To Event Counter

The byte written to the data bus buffer (with $A_0 = 0$) following this command will be loaded into the Event Counter Register and the Event Counter Status for byte counting or EOI counting. Only $\overline{\text{IBFI}}$ will indicate completion of this command.

E3 — REVC — Read Event Counter Status

This command transfers the contents of the Event Counter into the data bus buffer. A TCI is generated when the data is available in the data bus buffer.

E4 — RERF — Read Error Flag Register

This command transfers the contents of the Error Flag Register into the data bus buffer. A TCI is generated when the data is available.

E5 — RINM — Read Interrupt Mask Register

This command transfers the contents of the Interrupt Mask Register into the data bus buffer. This register is available to the processor so that it does not need to store this information elsewhere. A TCI is generated when the data is available in the data bus buffer.

E6 — RCST — Read Controller Status Register

This command transfers the contents of the Controller Status Register into the data bus buffer and a TCI interrupt is generated.

E7 — RBST — Read GPIB Bus Status Register

This command transfers the contents of the GPIB Bus Status Register into the data bus buffer, and a TCI interrupt is generated when the data is available.

E9 — RTOUT — Read Time Out Status Register

This command transfers the contents of the Time Out Status Register into the data bus buffer, and a TCI interrupt is generated when the data is available.

EA — RERM — Read Error Mask Register

This command transfers the contents of the Error Mask Register to the data bus buffer so that the processor does not need to store this information elsewhere. A TCI interrupt is generated when the data is available.

Interrupt Acknowledge

SYC	ERR	SRQ	EV	1	IFCR	1	1
D_7							D_0

Each named bit in an Interrupt Acknowledge (IACK) corresponds to a flag in the Interrupt Status Register. When the 8292 receives this command, it will clear the SPI and the corresponding bits in the Interrupt Status Register. If not all the bits were cleared, then the SPI will be set true again. If the error flag is not acknowledged by the IACK command, then the Error Flag Register will be transferred to the data bus buffer, and a TCI will be generated.

NOTE: XXXX1X11 is an undefined operation or utility command, so no conflict exists between the IACK operation and utility commands.

SYSTEM OPERATION

8292 To Master Processor Interface

Communication between the 8292 and the Master Processor can be either interrupt based communication or based upon polling the interrupt status register in predetermined intervals.

Interrupt Based Communication

Four different interrupts are available from the 8292:

OBFI Output Buffer Full Interrupt

$\overline{\text{IBFI}}$ Input Buffer Not Full Interrupt

TCI Task Completed Interrupt

SPI Special Interrupt

Each of the interrupts is enabled or disabled by a bit in the interrupt mask register. Since OBFI and $\overline{\text{IBFI}}$ are directly connected to the OBF and IBF flags, the master can write a new command to the input data bus buffer as soon as the previous command has been read.

The TCI interrupt is useful when the master is sending commands to the 8292. The pending TCI will be cleared with each new command written to the 8292. Commands sent to the 8292 can be divided into two major groups:

1. Commands that require response back from the 8292 to the master, e.g., reading register.
2. Commands that initiate some action or enable features but do not require response back from the 8292, e.g., enable data bus buffer interrupts.

With the first group, the TCI interrupt will be used to indicate that the required response is ready in the data bus buffer and the master may continue and read it. With the second group, the interrupt will be used to indicate completion of the required task, so that the master may send new commands.

The SPI should be used when immediate information or special events is required (see the Interrupt Status Register).

"Polling Status" Based Communication

When interrupt based communication is not desired, all interrupts can be masked by the interrupt mask register. The communication with the 8292 is based upon sequential poll of the interrupt status register. By testing the OBF and IBF flags, the data bus buffer status is determined while special events are determined by testing the other bits.

Receiving IFC

The IFC pulse defined by the IEEE-488 standard is at least 100 μsec. In this time, all operation on the bus should be aborted. Most important, the current controller (the one that is in charge at that time) should stop sending ATN or EOI. Thus, IFC must externally gate $\overline{\text{CIC}}$ (controller in charge) and $\overline{\text{ATNO}}$ to ensure that this occurs.

Reset and Power Up Procedure

After the 8292 has been reset either by the external reset pin, the device being powered on, or a RST command, the following sequential events will take place:

1. All outputs to the GPIB interface will go high ($\overline{\text{SRQ}}$, $\overline{\text{ATNI}}$, $\overline{\text{IFC}}$, SYC, CLTH, $\overline{\text{ATNO}}$, $\overline{\text{CIC}}$, TCI, SPI, $\overline{\text{EOI}}$, OBFI, $\overline{\text{IBFI}}$, $\overline{\text{DAV}}$, $\overline{\text{REV}}$).
2. The four interrupt outputs (TCI, SPI, OBFI, $\overline{\text{IBFI}}$) and CLTH output will go low.
3. The following registers will be cleared:
   Interrupt Status
   Interrupt Mask
   Error Flag
   Error Mask
   Time Out
   Event Counter (= 256), Counter is disabled.
4. If the 8292 is the system controller, an ABORT command will be executed, the 8292 will become the controller in charge, and it will enter the CACS state.

   If it is not the system controller, it will remain in CIDS.

System Configuration

The 8291 and 8292 must be interfaced to an IEEE-488 bus meeting a variety of specifications including drive capability and loading characteristics. To interface the 8291 and the 8292 without the 8293's, several external gates are required, using a configuration similar to that used in Figure 5.

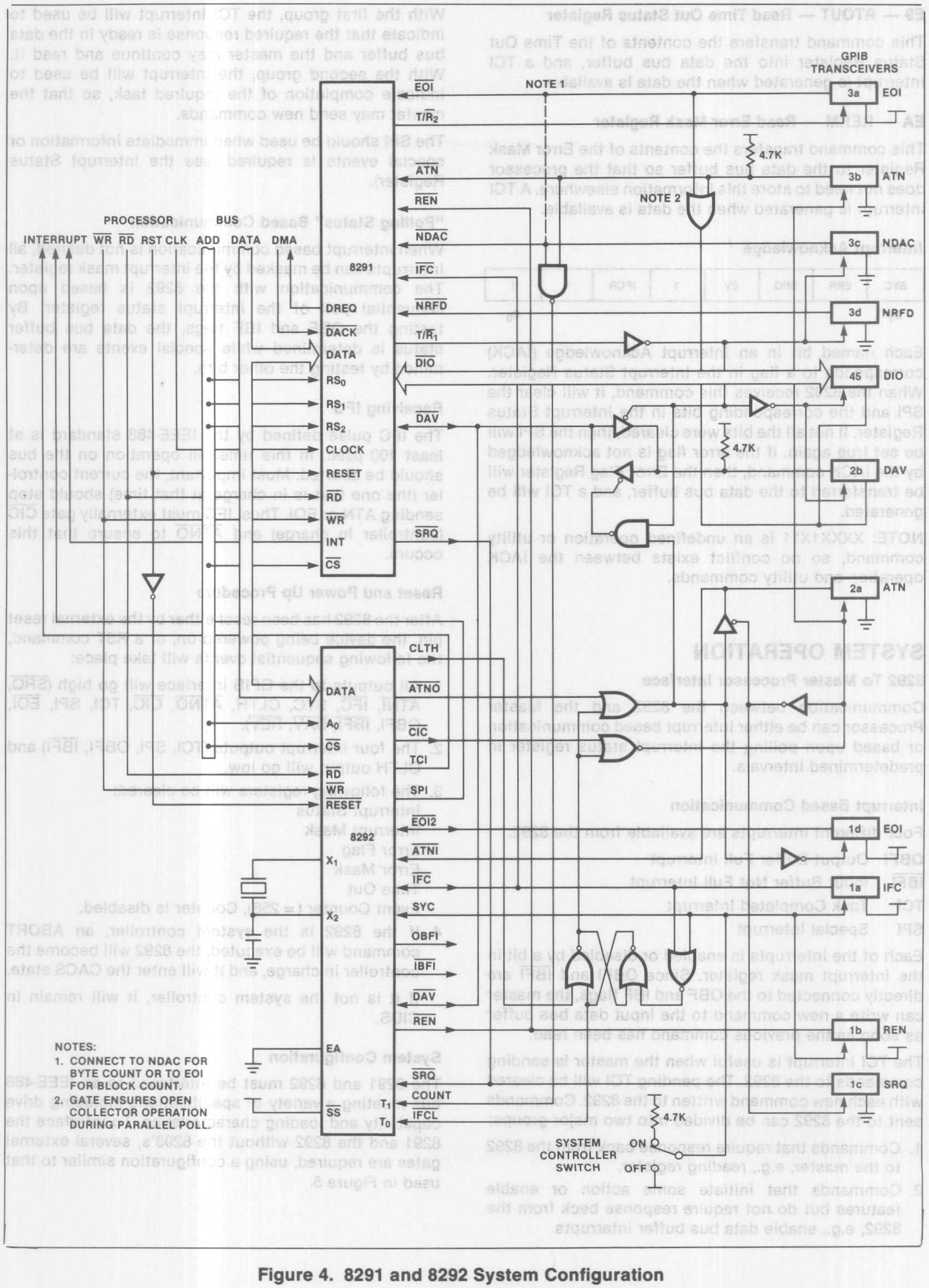

Figure 4. 8291 and 8292 System Configuration

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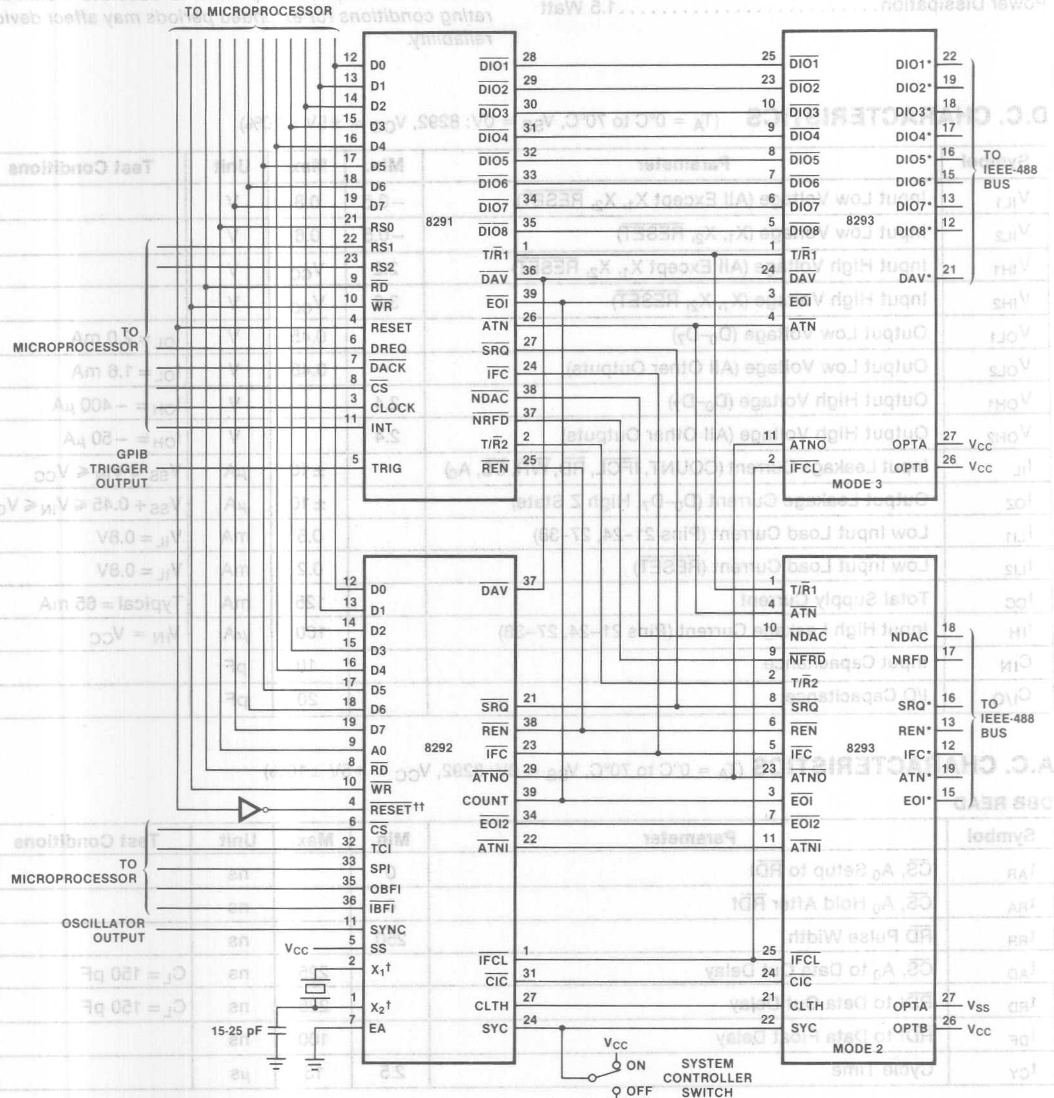

* = GPIB BUS TRANSCEIVER
† = SEE 8041A DATA SHEET FOR ALTERNATE CRYSTAL CONFIGURATIONS
†† = CAN CONNECT TO SYSTEM RESET SWITCH, SEE 8041A DATA SHEET

Figure 5. 8291, 8292, and 8293 System Configuration

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Ambient Temperature Under Bias.........0°C to 70°C
Storage Temperature.............−65°C to +150°C
Voltage on Any Pin With Respect
to Ground...........................0.5V to +7V
Power Dissipation.........................1.5 Watt

Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

D.C. CHARACTERISTICS (T_A = 0°C to 70°C, V_{SS} = 0V: 8292, V_{CC} = ±5V ±10%)

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
V_{IL1}	Input Low Voltage (All Except X_1, X_2, $\overline{RESET}$)	−0.5	0.8	V	
V_{IL2}	Input Low Voltage (X_1, X_2, $\overline{RESET}$)	−0.5	0.6	V	
V_{IH1}	Input High Voltage (All Except X_1, X_2, $\overline{RESET}$)	2.2	V_{CC}	V	
V_{IH2}	Input High Voltage (X_1, X_2, $\overline{RESET}$)	3.8	V_{CC}	V	
V_{OL1}	Output Low Voltage (D_0–D_7)		0.45	V	I_{OL} = 2.0 mA
V_{OL2}	Output Low Voltage (All Other Outputs)		0.45	V	I_{OL} = 1.6 mA
V_{OH1}	Output High Voltage (D_0–D_7)	2.4		V	I_{OH} = −400 μA
V_{OH2}	Output High Voltage (All Other Outputs)	2.4		V	I_{OH} = −50 μA
I_{IL}	Input Leakage Current (COUNT, $\overline{IFCL}$, $\overline{RD}$, $\overline{WR}$, $\overline{CS}$, A_0)		±10	μA	$V_{SS} \leq V_{IN} \leq V_{CC}$
I_{OZ}	Output Leakage Current (D_0–D_7, High Z State)		±10	μA	$V_{SS} + 0.45 \leq V_{IN} \leq V_{CC}$
I_{LI1}	Low Input Load Current (Pins 21-24, 27-38)		0.5	mA	V_{IL} = 0.8V
I_{LI2}	Low Input Load Current ($\overline{RESET}$)		0.2	mA	V_{IL} = 0.8V
I_{CC}	Total Supply Current		125	mA	Typical = 65 mA
I_{IH}	Input High Leakage Current (Pins 21–24, 27–38)		100	μA	$V_{IN} = V_{CC}$
C_{IN}	Input Capacitance		10	pF	
$C_{I/O}$	I/O Capacitance		20	pF	

A.C. CHARACTERISTICS (T_A = 0°C to 70°C, V_{SS} = 0V: 8292, V_{CC} = +5V ±10%)

DBB READ

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AR}	$\overline{CS}$, A_0 Setup to $\overline{RD}$↓	0		ns	
t_{RA}	$\overline{CS}$, A_0 Hold After $\overline{RD}$↑	0		ns	
t_{RR}	$\overline{RD}$ Pulse Width	250		ns	
t_{AD}	$\overline{CS}$, A_0 to Data Out Delay		225	ns	C_L = 150 pF
t_{RD}	$\overline{RD}$↓ to Data Out Delay		225	ns	C_L = 150 pF
t_{DF}	$\overline{RD}$↑ to Data Float Delay		100	ns	
t_{CY}	Cycle Time	2.5	15	μs	

DBB WRITE

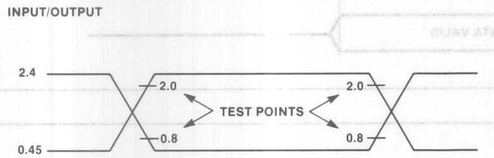
Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	CS, A_0 Setup to WR↓	0		ns	
t_{WA}	CS, A_0 Hold After WR↑	0		ns	
t_{WW}	WR Pulse Width	250		ns	
t_{DW}	Data Setup to WR↑	150		ns	
t_{WD}	Data Hold After WR↓	0		ns	

COMMAND TIMINGS[1,3]

Code	Name	Execution Time	$\overline{IBFI}\uparrow$	TCI[2]	SPI	$\overline{ATNO}$	$\overline{CIC}$	$\overline{IFC}$	$\overline{REN}$	$\overline{EOI}$	$\overline{DAV}$	Comments
E1	WTOUT	63	24									
E2	WEVC	63	24									
E3	REVC	71	24	51								
E4	RERF	67	24	47								
E5	RINM	69	24	49								
E6	RCST	97	24	77								
E7	RBST	92	24	72								
E8												
E9	RTOUT	69	24	49								
EA	RERM	69	24	49								
F0	SPCNI	53	24									Count Stops After 39
F1	GIOL	88	24	70		↑61	↑61					
F2	RST	94	24		↓52							Not System Controller
F2	RST	214	24	192	↓52	↓179	↓174	↓101				System Controller
F3	RSTI	61	24									
F4	GSEC	125	24	107		↑98						
F5	EXPP	75	24						↓53 ↑59	↓55 ↑57		
F6	GTSB	118	24	100		↑91						
F7	SLOC	73	24	55				↑46				
F8	SREM	91	24	73				↓64				
F9	ABORT	155	24	133		↓120	↓115	↓42				
FA	TCNTR	108	24	86		↓71	↓68					
FC	TCAS	92	24	67		↓55						
FD	TCSY	115	24	91		↓80						
FE	STCNI	59	24									Starts Count After 43
PIN	RESET	29	—	↓7	↓7							Not System Controller
X	IACK	116	—		↓73 ↑98							If Interrupt Pending

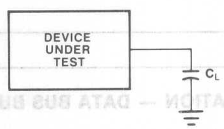
Notes:
1. All times are multiples of t_{CY} from the 8041A command interrupt.
2. TCI clears after 7 t_{CY} on all commands.
3. ↑ indicates a level transition from low to high, ↓ indicates a high to low transition.

A.C. TESTING INPUT, OUTPUT WAVEFORM



A.C. TESTING: INPUTS ARE DRIVEN AT 2.4V FOR A LOGIC "1" AND 0.45V FOR A LOGIC "0." TIMING MEASUREMENTS ARE MADE AT 2.0V FOR A LOGIC "1" AND 0.8V FOR A LOGIC "0."

A.C. TESTING LOAD CIRCUIT

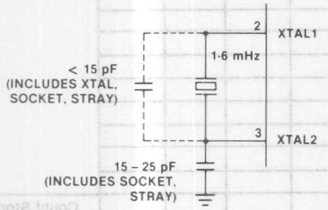


C_L INCLUDES JIG CAPACITANCE

AFN-00741D

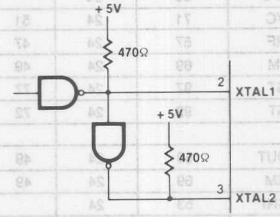
CLOCK DRIVER CIRCUITS

CRYSTAL OSCILLATOR MODE



CRYSTAL SERIES RESISTANCE SHOULD BE <75Ω AT 6 MHz; <180Ω AT 3.6 MHz.

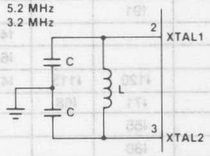
DRIVING FROM EXTERNAL SOURCE



BOTH XTAL1 AND XTAL2 SHOULD BE DRIVEN. RESISTORS TO V_{CC} ARE NEEDED TO ENSURE $V_{IH} = 3.8V$ IF TTL CIRCUITRY IS USED.

LC OSCILLATOR MODE

L	C	NOMINAL f
45 μH	20 pF	5.2 MHz
120 μH	20 pF	3.2 MHz



$f = \frac{1}{2\pi\sqrt{LC'}}$

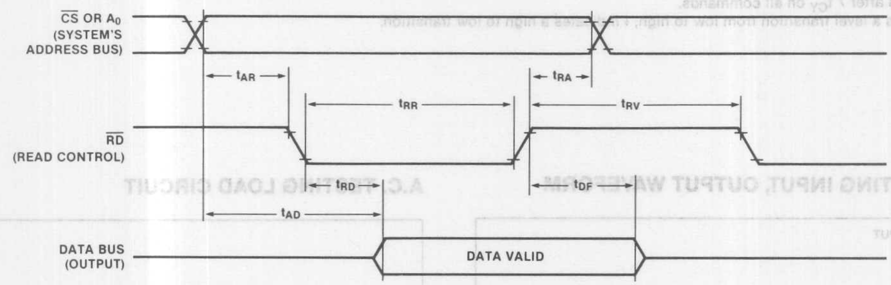
$C' = \frac{C + 3C_{PP}}{2}$

$C_{PP} \approx 5 – 10$ pF PIN-TO-PIN CAPACITANCE

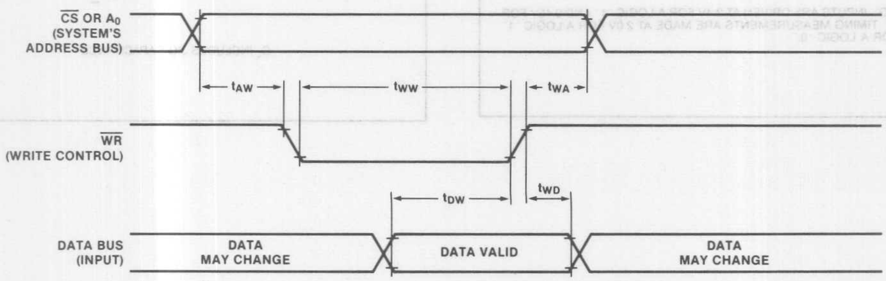
EACH C SHOULD BE APPROXIMATELY 20 pF, INCLUDING STRAY CAPACITANCE.

WAVEFORMS

READ OPERATION—DATA BUS BUFFER REGISTER



WRITE OPERATION — DATA BUS BUFFER REGISTER



APPENDIX

The following tables and state diagrams were taken from the IEEE Standard Digital Interface for Programmable Instrumentation, IEEE Std. 488-1978. This document is the official standard for the GPIB bus and can be purchased from IEEE, 345 East 47th St., New York, NY 10017.

C MNEMONICS

Messages	Interface States
pon = power on	CIDS = controller idle state
rsc = request system control	CADS = controller addressed state
rpp = request parallel poll	CTRS = controller transfer state
gts = go to standby	CACS = controller active state
tca = take control asynchronously	CPWS = controller parallel poll wait state
tcs = take control synchronously	CPPS = controller parallel poll state
sic = send interface clear	CSBS = controller standby state
sre = send remote enable	CSHS = controller standby hold state
IFC = interface clear	CAWS = controller active wait state
ATN = attention	CSWS = controller synchronous wait state
TCT = take control	CSRS = controller service requested state
	CSNS = controller service not requested state
	SNAS = system control not active state
	SACS = system control active state
	SRIS = system control remote enable idle state
	SRNS = system control remote enable not active state
	SRAS = system control remote enable active state
	SIIS = system control interface clear idle state
	SINS = system control interface clear not active state
	SIAS = system control interface clear active state
	ACDS = accept data state (AH function)
	ANRS = acceptor not ready state (AH function)
	SDYS = source delay state (SH function)
	STRS = source transfer state (SH function)
	TADS = talker addressed state (T function)

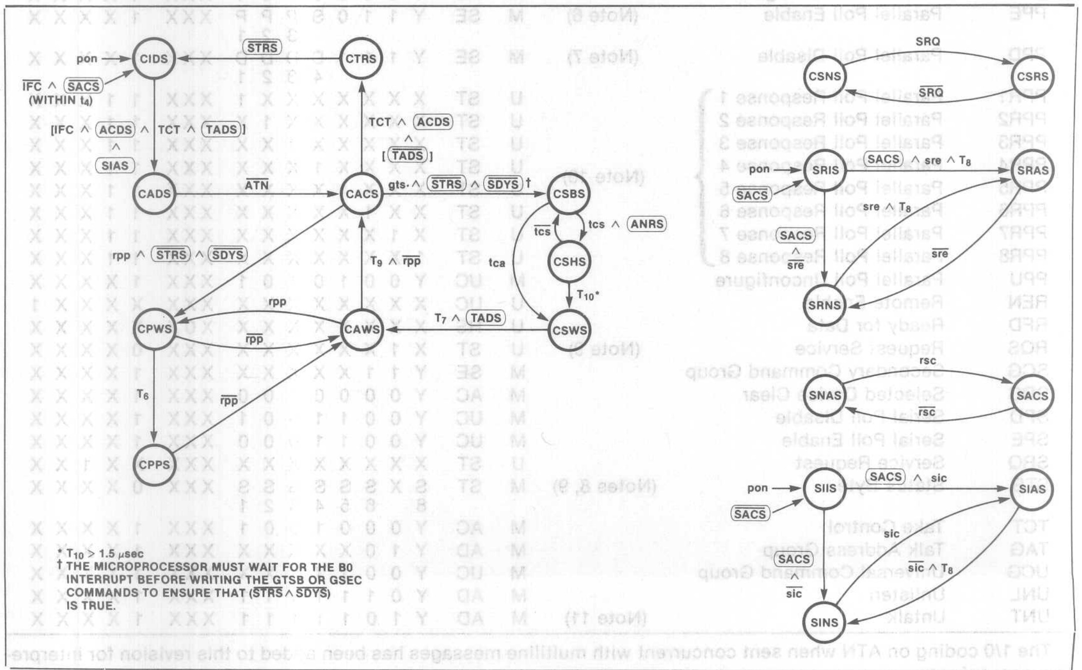


Figure A.1. C State Diagram

AFN-00741D

Mnemonic	Message Name		TYPE	CLASS	DIO8	7	6	5	4	3	2	DIO1	DAV	NRFD	NDAC	ATN	EOI	SRQ	IFC	REN
					Bus Signal Line(s) and Coding That Asserts the True Value of the Message															
ACG	Addressed Command Group		M	AC	Y	0	0	0	X	X	X	X	X	X	X	1	X	X	X	X
ATN	Attention		U	UC	X	X	X	X	X	X	X	X	X	X	X	1	X	X	X	X
DAB	Data Byte	(Notes 1, 9)	M	DD	D8	D7	D6	D5	D4	D3	D2	D1	X	X	X	0	X	X	X	X
DAC	Data Accepted		U	HS	X	X	X	X	X	X	X	X	X	X	0	X	X	X	X	X
DAV	Data Valid		U	HS	X	X	X	X	X	X	X	X	1	X	X	X	X	X	X	X
DCL	Device Clear		M	UC	Y	0	0	1	0	1	0	0	X	X	X	1	X	X	X	X
END	End		U	ST	X	X	X	X	X	X	X	X	X	X	X	0	1	X	X	X
EOS	End of String	(Notes 2, 9)	M	DD	E8	E7	E6	E5	E4	E3	E2	E1	X	X	X	0	X	X	X	X
GET	Group Execute Trigger		M	AC	Y	0	0	0	1	0	0	0	X	X	X	1	X	X	X	X
GTL	Go to Local		M	AC	Y	0	0	0	0	0	0	1	X	X	X	1	X	X	X	X
IDY	Identify		U	UC	X	X	X	X	X	X	X	X	X	X	X	X	1	X	X	X
IFC	Interface Clear		U	UC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1	X
LAG	Listen Address Group		M	AD	Y	0	1	X	X	X	X	X	X	X	X	1	X	X	X	X
LLO	Local Lock Out		M	UC	Y	0	0	1	0	0	0	1	X	X	X	1	X	X	X	X
MLA	My Listen Address	(Note 3)	M	AD	Y	0	1	L5	L4	L3	L2	L1	X	X	X	1	X	X	X	X
MTA	My Talk Address	(Note 4)	M	AD	Y	1	0	T5	T4	T3	T2	T1	X	X	X	1	X	X	X	X
MSA	My Secondary Address	(Note 5)	M	SE	Y	1	1	S5	S4	S3	S2	S1	X	X	X	1	X	X	X	X
NUL	Null Byte		M	DD	0	0	0	0	0	0	0	0	X	X	X	X	X	X	X	X
OSA	Other Secondary Address		M	SE	$(OSA = SCG \wedge \overline{MSA})$															
OTA	Other Talk Address		M	AD	$(OTA = TAG \wedge \overline{MTA})$															
PCG	Primary Command Group		M	—	$(PCG = ACG \vee UCG \vee LAG \vee TAG)$															
PPC	Parallel Poll Configure		M	AC	Y	0	0	0	0	1	0	1	X	X	X	1	X	X	X	X
PPE	Parallel Poll Enable	(Note 6)	M	SE	Y	1	1	0	S	P3	P2	P1	X	X	X	1	X	X	X	X
PPD	Parallel Poll Disable	(Note 7)	M	SE	Y	1	1	1	D4	D3	D2	D1	X	X	X	1	X	X	X	X
PPR1	Parallel Poll Response 1		U	ST	X	X	X	X	X	X	X	1	X	X	X	1	1	X	X	X
PPR2	Parallel Poll Response 2		U	ST	X	X	X	X	X	X	1	X	X	X	X	1	1	X	X	X
PPR3	Parallel Poll Response 3		U	ST	X	X	X	X	X	1	X	X	X	X	X	1	1	X	X	X
PPR4	Parallel Poll Response 4	(Note 10)	U	ST	X	X	X	X	1	X	X	X	X	X	X	1	1	X	X	X
PPR5	Parallel Poll Response 5		U	ST	X	X	X	1	X	X	X	X	X	X	X	1	1	X	X	X
PPR6	Parallel Poll Response 6		U	ST	X	X	1	X	X	X	X	X	X	X	X	1	1	X	X	X
PPR7	Parallel Poll Response 7		U	ST	X	1	X	X	X	X	X	X	X	X	X	1	1	X	X	X
PPR8	Parallel Poll Response 8		U	ST	1	X	X	X	X	X	X	X	X	X	X	1	1	X	X	X
PPU	Parallel Poll Unconfigure		M	UC	Y	0	0	1	0	1	0	1	X	X	X	1	X	X	X	X
REN	Remote Enable		U	UC	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1
RFD	Ready for Data		U	HS	X	X	X	X	X	X	X	X	X	0	X	X	X	X	X	X
RQS	Request Service	(Note 9)	U	ST	X	1	X	X	X	X	X	X	X	X	X	0	X	X	X	X
SCG	Secondary Command Group		M	SE	Y	1	1	X	X	X	X	X	X	X	X	1	X	X	X	X
SDC	Selected Device Clear		M	AC	Y	0	0	0	0	1	0	0	X	X	X	1	X	X	X	X
SPD	Serial Poll Disable		M	UC	Y	0	0	1	1	0	0	1	X	X	X	1	X	X	X	X
SPE	Serial Poll Enable		M	UC	Y	0	0	1	1	0	0	0	X	X	X	1	X	X	X	X
SRQ	Service Request		U	ST	X	X	X	X	X	X	X	X	X	X	X	X	X	1	X	X
STB	Status Byte	(Notes 8, 9)	M	ST	S8	X	S6	S5	S4	S3	S2	S1	X	X	X	0	X	X	X	X
TCT	Take Control		M	AC	Y	0	0	0	1	0	0	1	X	X	X	1	X	X	X	X
TAG	Talk Address Group		M	AD	Y	1	0	X	X	X	X	X	X	X	X	1	X	X	X	X
UCG	Universal Command Group		M	UC	Y	0	0	1	X	X	X	X	X	X	X	1	X	X	X	X
UNL	Unlisten		M	AD	Y	0	1	1	1	1	1	1	X	X	X	1	X	X	X	X
UNT	Untalk	(Note 11)	M	AD	Y	1	0	1	1	1	1	1	X	X	X	1	X	X	X	X

The 1/0 coding on ATN when sent concurrent with multiline messages has been added to this revision for interpretive convenience.

NOTES:

1. D1–D8 specify the device dependent data bits.
2. E1–E8 specify the device dependent code used to indicate the EOS message.
3. L1–L5 specify the device dependent bits of the device's listen address.
4. T1–T5 specify the device dependent bits of the device's talk address.
5. S1–S5 specify the device dependent bits of the device's secondary address.
6. S specifies the sense of the PPR.

   Response = $\overline{S \oplus ist}$

P1–P3 specify the PPR message to be sent when a parallel poll is executed.

P3	P2	P1	PPR Message
0	0	0	PPR1
.	.	.	.
.	.	.	.
.	.	.	.
1	1	1	PPR8

7. D1–D4 specify don't-care bits that shall not be decoded by the receiving device. It is recommended that all zeroes be sent.
8. S1–S6, S8 specify the device dependent status. (DIO7 is used for the RQS message.)
9. The source of the message on the ATN line is always the C function, whereas the messages on the DIO and EOI lines are enabled by the T function.
10. The source of the messages on the ATN and EOI lines is always the C function, whereas the source of the messages on the DIO lines is always the PP function.
11. This code is provided for system use, see 6.3.

8294
DATA ENCRYPTION UNIT

- Certified by National Bureau of Standards
- 80 Byte/Sec Data Conversion Rate
- 64-Bit Data Encryption Using 56-Bit Key
- DMA Interface
- 3 Interrupt Outputs to Aid in Loading and Unloading Data
- 7-Bit User Output Port
- Single 5V ± 10% Power Supply
- Peripheral to MCS-86™, MCS-85™, MCS-80™ and MCS-48™ Processors
- Implements Federal Information Processing Data Encryption Standard
- Encrypt and Decrypt Modes Available

The Intel® 8294 Data Encryption Unit (DEU) is a microprocessor peripheral device designed to encrypt and decrypt 64-bit blocks of data using the algorithm specified in the Federal Information Processing Data Encryption Standard. The DEU operates on 64-bit text words using a 56-bit user-specified key to produce 64-bit cipher words. The operation is reversible: if the cipher word is operated upon, the original text word is produced. The algorithm itself is permanently contained in the 8294; however, the 56-bit key is user-defined and may be changed at any time.

The 56-bit key and 64-bit message data are transferred to and from the 8294 in 8-bit bytes by way of the system data bus. A DMA interface and three interrupt outputs are available to minimize software overhead associated with data transfer. Also, by using the DMA interface two or more DEUs may be operated in parallel to achieve effective system conversion rates which are virtually any multiple of 80 bytes/second. The 8294 also has a 7-bit TTL compatible output port for user-specified functions.

Because the 8294 implements the NBS encryption algorithm it can be used in a variety of Electronic Funds Transfer applications as well as other electronic banking and data handling applications where data must be encrypted.

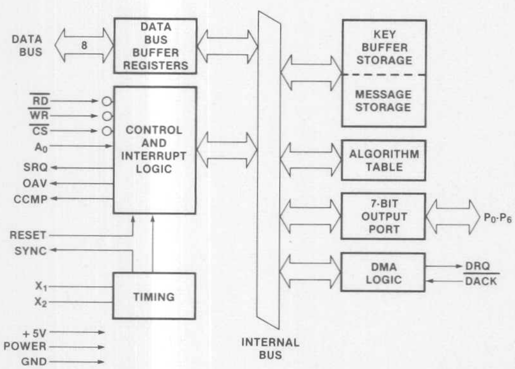


Figure 1. Block Diagram

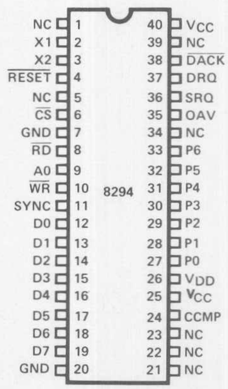


Figure 2. Pin Configuration

Table 1. Pin Description

Symbol	Pin No.	Type	Name and Function
NC	1		**No Connection.**
X1 X2	2 3	I	**Crystal:** Inputs for crystal, L-C or external timing signal to determine internal oscillator frequency.
$\overline{RESET}$	4	I	**Reset:** A low signal to this pin resets the 8294.
NC	5		**No Connection:** No connection or tied high.
$\overline{CS}$	6	I	**Chip Select:** A low signal to this pin enables reading and writing to the 8294.
GND	7		**Ground:** This pin must be tied to ground.
$\overline{RD}$	8	I	**Read:** An active low read strobe at this pin enables the CPU to read data and status from the internal DEU registers.
A_0	9	I	**Address:** Address input used by the CPU to select DEU registers during read and write operations.
$\overline{WR}$	10	I	**Write:** An active low write strobe at this pin enables the CPU to send data and commands to the DEU.
SYNC	11	O	**Sync:** High frequency (Clock ÷ 15) output. Can be used as a strobe for external circuitry.
D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7	12 13 14 15 16 17 18 19	I/O	**Data Bus:** Three-state, bi-directional data bus lines used to transfer data between the CPU and the 8294.
GND	20		**Ground:** This pin must be tied to ground.
V_{CC}	40		**Power:** +5 volt power input: +5V ± 10%.
NC	39		**No Connection.**
$\overline{DACK}$	38	I	**DMA Acknowledge:** Input signal from the 8257 DMA Controller acknowledging that the requested DMA cycle has been granted.
DRQ	37	O	**DMA Request:** Output signal to the 8257 DMA Controller requesting a DMA cycle.
SRQ	38	O	**Service Request:** Interrupt to the CPU indicating that the 8294 is awaiting data or commands at the input buffer. SRQ=1 implies IBF=0.
OAV	35	O	**Output Available:** Interrupt to the CPU indicating that the 8294 has data or status available in its output buffer. OAV=1 implies OBF=1.
NC	34		**No Connection.**
P6 P5 P4 P3 P2 P1 P0	33 32 31 30 29 28 27	O	**Output Port:** User output port lines. Output lines available to the user via a CPU command which can assert selected port lines. These lines have nothing to do with the encryption function. At power-on, each line is in a 1 state.
V_{DD}	26		**Power:** +5V power input. (+5V ±10%) Low power standby pin.
V_{CC}	25		**Power:** Tied high.
CCMP	24	O	**Conversion Complete:** Interrupt to the CPU indicating that the encryption/decryption of an 8-byte block is complete.
NC	23		**No Connection.**
NC	22		**No Connection.**
NC	21		**No Connection.**

The data conversion sequence is as follows:

1. A Set Mode command is given, enabling the desired interrupt outputs.
2. An Enter New Key command is issued, followed by 8 data inputs which are retained by the DEU for encryption/decryption. Each byte must have odd parity.
3. An Encrypt Data or Decrypt Data command sets the DEU in the desired mode.

After this, data conversions are made by writing 8 data bytes and then reading back 8 converted data bytes. Any of the above commands may be issued between data conversions to change the basic operation of the DEU; e.g., a Decrypt Data command could be issued to change the DEU from encrypt mode to decrypt mode without changing either the key or the interrupt outputs enabled.

INTERNAL DEU REGISTERS

Four internal registers are addressable by the master processor: 2 for input, and 2 for output. The following table describes how these registers are accessed.

$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	A_0	Register
1	0	0	0	Data input buffer
0	1	0	0	Data output buffer
1	0	0	1	Command input buffer
0	1	0	1	Status output buffer
X	X	1	X	Don't care

The functions of each of these registers are described below.

Data Input Buffer — Data written to this register is interpreted in one of three ways, depending on the preceding command sequence.

1. Part of a key.
2. Data to be encrypted or decrypted.
3. A DMA block count.

Data Output Buffer — Data read from this register is the output of the encryption/decryption operation.

Command Input Buffer — Commands to the DEU are written into this register. (See command summary below.)

Status Output Buffer — DEU status is available in this register at all times. It is used by the processor for poll-driven command and data transfer operations.

STATUS BIT:	7	6	5	4	3	2	1	0
FUNCTION:	X	X	X	KPE	CF	DEC	IBF	OBF

OBF Output Buffer Full; OBF = 1 indicates that output from the encryption/decryption function is available in the Data Output Buffer. It is reset when the data is read.

DEU resets this flag when it has accepted the input byte. Nothing should be written when IBF = 1.

DEC Decrypt; indicates whether the DEU is in an encrypt or a decrypt mode. DEC = 1 implies the decrypt mode. DEC = 0 implies the encrypt mode.

CF Completion Flag; This flag may be used to indicate any or all of three events in the data transfer protocol.

1. It may be used in lieu of a counter in the processor routine to flag the end of an 8-byte transfer.
2. It must be used to indicate the validity of the KPE flag.
3. It may be used in lieu of the CCMP interrupt to indicate the completion of a DMA operation.

KPE Key Parity Error; After a new key has been entered, the DEU uses this flag in conjunction with the CF flag to indicate correct or incorrect parity.

COMMAND SUMMARY

1 — Enter New Key

OP CODE:	0	1	0	0	0	0	0	0
	MSB							LSB

This command is followed by 8 data byte inputs which are retained in the key buffer (RAM) to be used in encrypting and decrypting data. These data bytes must have odd parity represented by the LSB.

2 — Encrypt Data

OP CODE:	0	0	1	1	0	0	0	0
	MSB							LSB

This command puts the 8294 into the encrypt mode.

3 — Decrypt Data

OP CODE:	0	0	1	0	0	0	0	0
	MSB							LSB

This command puts the 8294 into the decrypt mode.

4 — Set Mode

OP CODE:	0	0	0	0	A	B	C	D
	MSB							LSB

where:

A is the OAV (Output Available) interrupt enable
B is the SRQ (Service Request) interrupt enable
C is the DMA (Direct Memory Access) transfer enable
D is the CCMP (Conversion Complete) interrupt enable

This command determines which interrupt outputs will be enabled. A "1" in bits A, B, or D will enable the OAV, SRQ, or CCMP interrupts respectively. A "1" in bit C will allow DMA transfers. When bit C is set the OAV and SRQ interrupts should also be enabled (bits A,B = 1). Following the command in which bit C, the DMA bit, is set, the 8294 will expect one data byte to specify the number of 8-byte blocks to be converted using DMA.

5 — Write to Output Port

OP CODE:

1	P_6	P_5	P_4	P_3	P_2	P_1	P_0
MSB							LSB

This command causes the 7 least significant bits of the command byte to be latched as output data on the 8294 output port. The initial output data is 1111111. Use of this port is independent of the encryption/decryption function.

PROCESSOR/DEU INTERFACE PROTOCOL

ENTERING A NEW KEY

The timing sequence for entering a new key is shown in Figure 3. A flowchart showing the CPU software to accommodate this sequence is given in Figure 4.

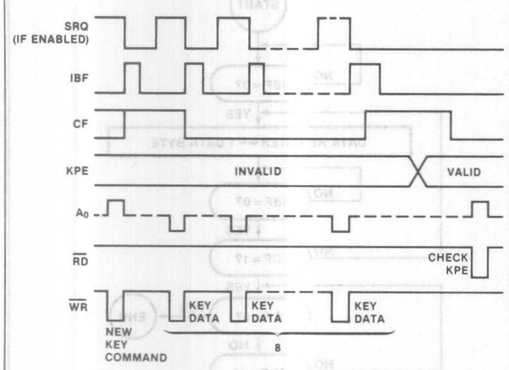


Figure 3. Entering a New Key

After the Enter New Key command is issued, 8 data bytes representing the new key are written to the data input buffer (most significant byte first). After the eighth byte is accepted by the DEU, CF goes true (CF = 1). The CF bit goes false again when KPE is valid. The CPU can then check the KPE flag. If KPE = 1, a parity error has been detected and the DEU has not accepted the key. Each byte is checked for odd parity, where the parity bit is the LSB of each byte.

Since the CF bit is used in this protocol to indicate the validity of the KPE flag, it may not be used to flag the end of the 8 byte key entry. CF = 1 only as long as KPE is invalid. Therefore, the CPU might not detect that CF = 1 and the key entry is complete before KPE becomes valid. Thus, a counter should be used, as in Figure 4, to flag the end of the new key entry. Then, CF is used to indicate a valid KPE flag.

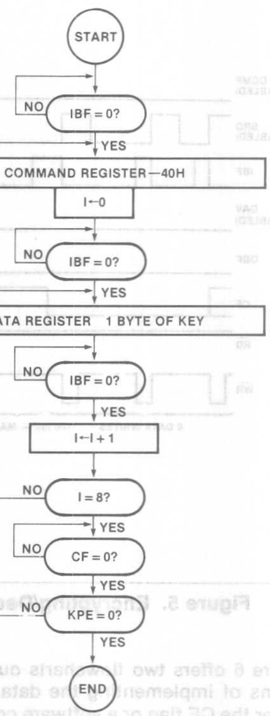


Figure 4. Flowchart for Entering a New Key

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ENCRYPTING OR DECRYPTING DATA

Figure 5 shows the timing sequence for encrypting or decrypting data. The CPU writes 8 data bytes to the DEU's data input buffer for encryption/decryption. CF then goes true (CF = 1) to indicate that the DEU has accepted the 8-byte block. Thus, the CPU may test for IBF = 0 and CF = 1 to terminate the input mode, or it may use a software counter. When the encryption/decryption is complete, the CCMP and OAV interrupts are asserted and the OBF flag is set true (OBF = 1). OAV and OBF are set false again after each of the converted data bytes is read back by the CPU. The CCMP interrupt is set false, and remains false, after the first read. After 8 bytes have been read back by the CPU, CF goes false (CF = 0). Thus, the CPU may test for CF = 0 to terminate the read mode. Also, the CCMP interrupt may be used to initiate a service routine which performs the next series of 8 data reads and 8 data writes.

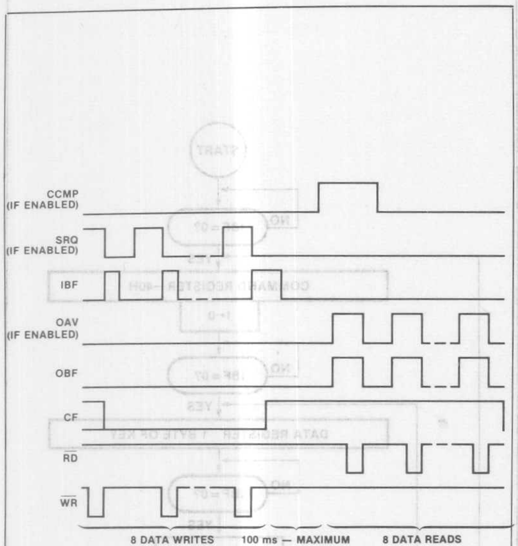


Figure 5. Encrypting/Decrypting Data

Figure 6 offers two flowcharts outlining the alternative means of implementing the data conversion protocol. Either the CF flag or a software counter may be used to end the read and write modes.

SRQ = 1 implies IBF = 0, OAV = 1 implies OBF = 1. This allows interrupt routines to do data transfers without checking status first. However, the OAV service routine must detect and flag the end of a data conversion.

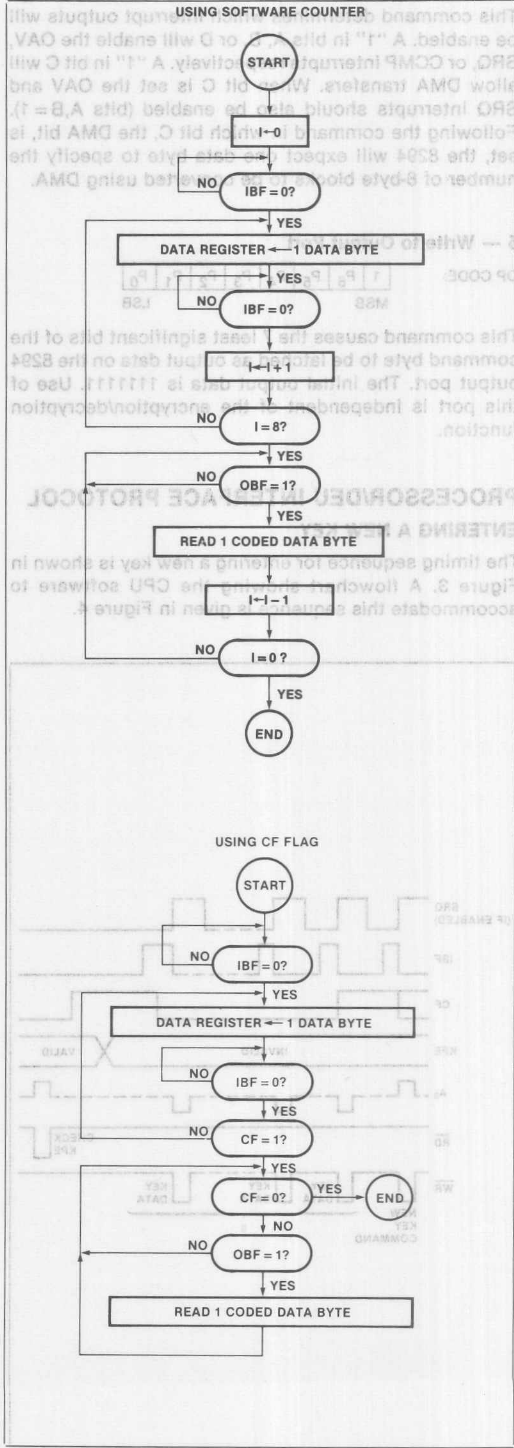


Figure 6. Data Conversion Flowcharts

USING DMA

The timing sequence for data conversions using DMA is shown in Figure 7. This sequence can be better understood when considered in conjunction with the hardware DMA interface in Figure 8. Note that the use of the DMA feature requires 3 external AND gates and 2 DMA channels (one for input, one for output). Since the DEU has only one DMA request pin, the SRQ and OAV outputs are used in conjunction with two of the AND gates to create separate DMA request outputs for the 2 DMA channels. The third AND gate combines the two active-low $\overline{DACK}$ inputs.

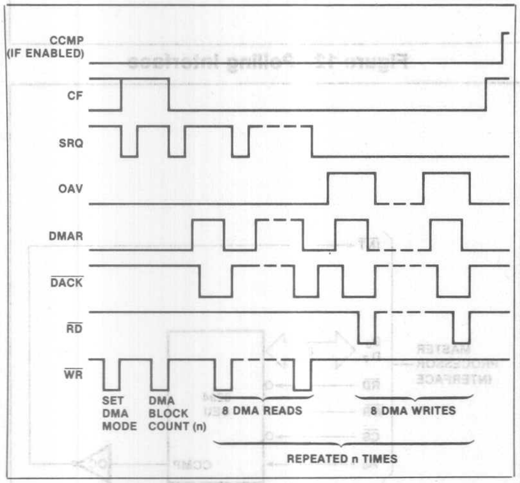


Figure 7. DMA Sequence

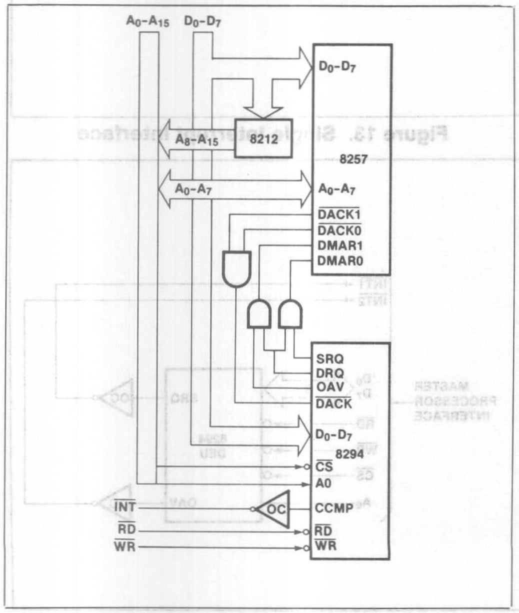


Figure 8. DMA Interface

To initiate a DMA transfer, the CPU must first initialize the two DMA channels as shown in the flowchart in Figure 9. It must then issue a Set Mode command to the DEU enabling the OAV, SRQ, and DMA outputs. The CCMP interrupt may be enabled or disabled, depending on whether that output is desired. Following the Set Mode command, there must be a data byte giving the number of 8-byte blocks of data (n<256) to be converted. The DEU then generates the required number of DMA requests to the 2 DMA channels with no further CPU intervention. When the requested number of blocks has been converted, the DEU will set CF and assert the CCMP interrupt (if enabled). CCMP then goes false again with the next write to the DEU (command or data). Upon completion of the conversion, the DMA mode is disabled and the DEU returns to the encrypt/decrypt mode. The enabled interrupt outputs, however, will remain enabled until another Set Mode command is issued.

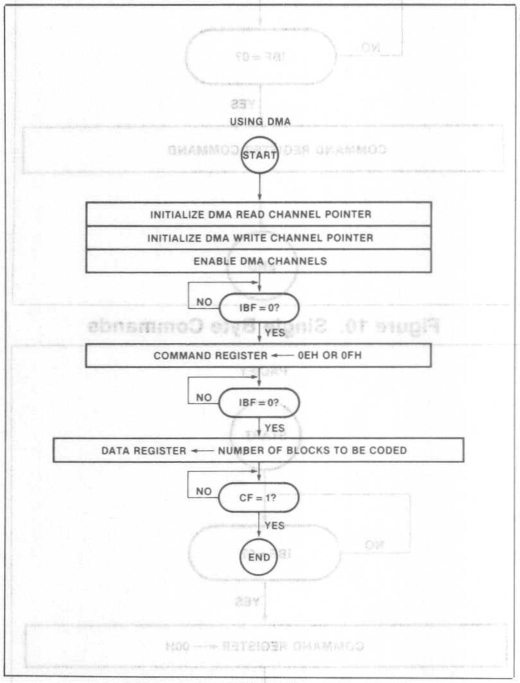


Figure 9. DMA Flowchart

SINGLE BYTE COMMANDS

Figure 10 shows the timing and protocol for single byte commands. Note that any of the commands is effective as a pacify command in that they may be entered at any time, except during a DMA conversion. The DEU is thus set to a known state. However, if a command is issued out of sequence, an additional protocol is required (Figure 11). The CPU must wait until the command is accepted (IBF = 0). A data read must then be issued to clear anything the preceding command sequence may have left in the Data Output Buffer.

tions used in the CPU/DEU data transfers. In all cases SRQ will be true (if enabled) and IBF will be false when the DEU is ready to accept data or commands.

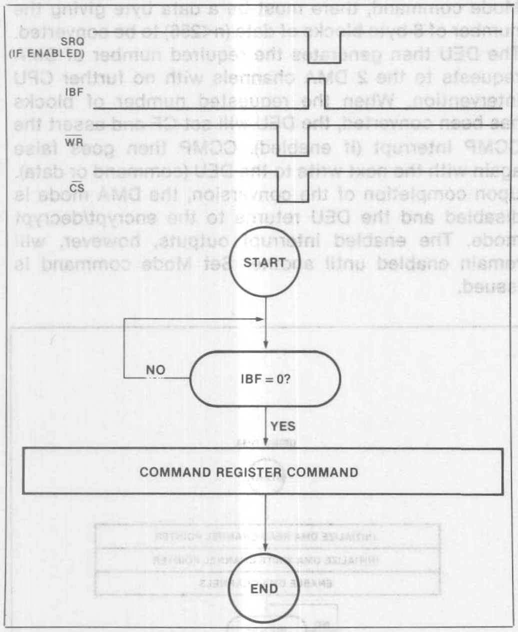


Figure 10. Single Byte Commands

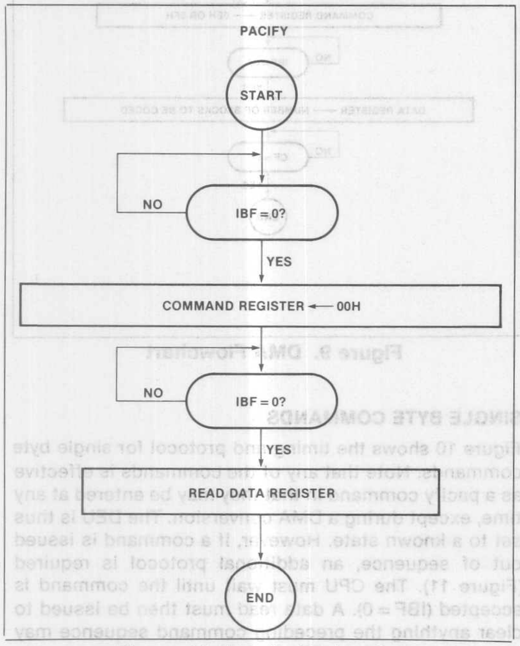


Figure 11. Pacify Protocol

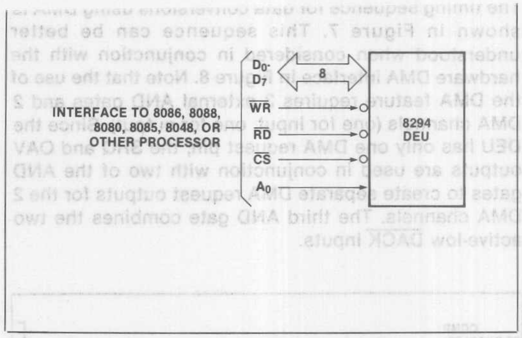


Figure 12. Polling Interface

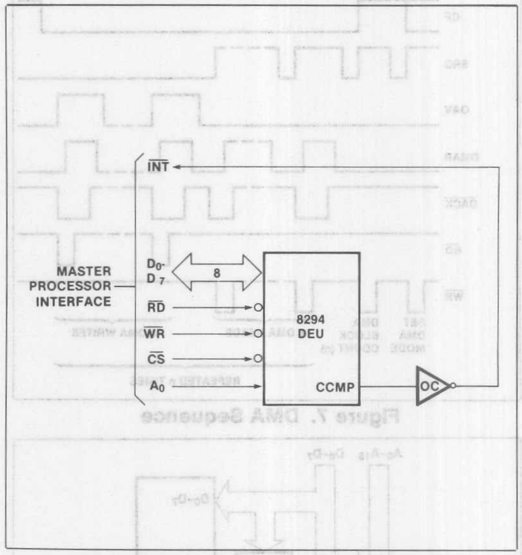


Figure 13. Single Interrupt Interface

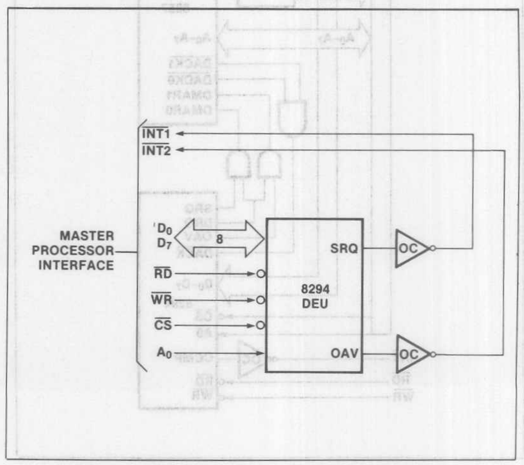


Figure 14. Dual Interrupt Interface

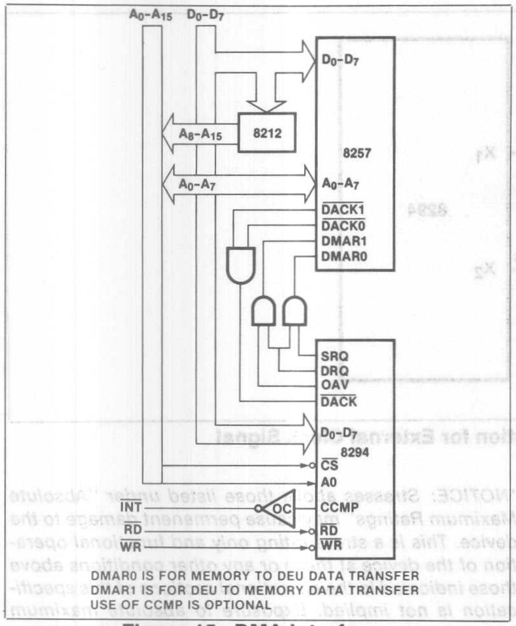


Figure 15. DMA Interface

OSCILLATOR AND TIMING CIRCUITS

The 8294's internal timing generation is controlled by a self-contained oscillator and timing circuit. A choice of crystal, L-C or external clock can be used to derive the basic oscillator frequency.

The resident timing circuit consists of an oscillator, a state counter and a cycle counter as illustrated in Figure 16.

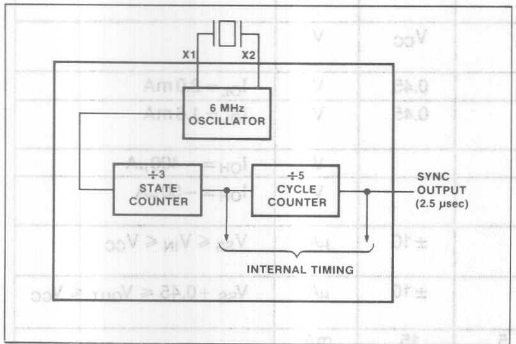


Figure 16. Oscillator Configuration

OSCILLATOR

The on-board oscillator is a series resonant circuit with a frequency range of 1 to 6 MHz. Pins X1 and X2 are input and output (respectively) of a high gain amplifier stage. A crystal or inductor and capacitator connected between X1 and X2 provide the feedback and proper phase shift for oscillation. Recommended connections for crystal or L-C are shown in Figure 17.

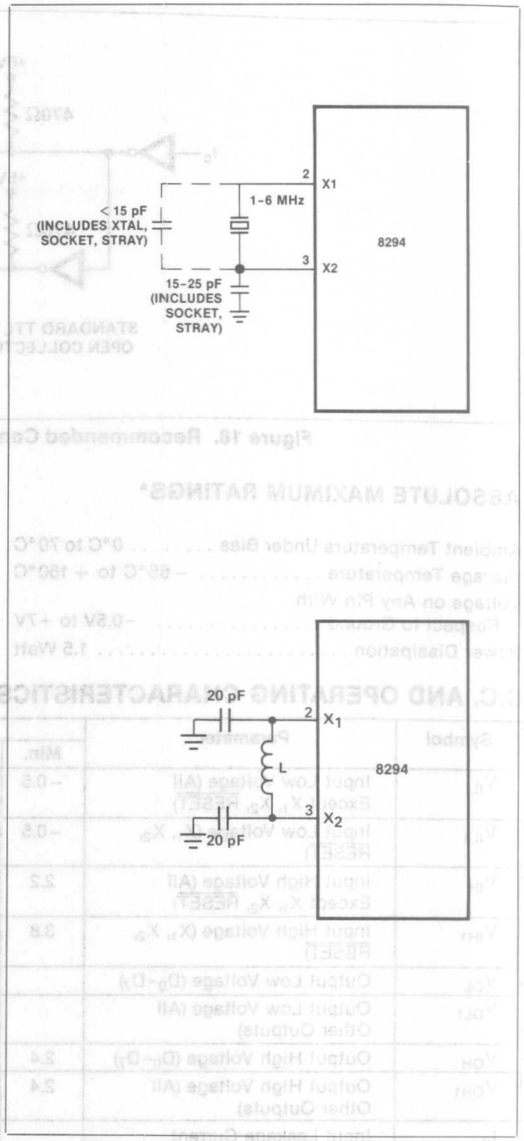


Figure 17. Recommended Crystal and L-C Connections

A recommended range of inductance and capacitance combinations is given below:

$L = 120\mu H$ corresponds to 3 MHz
$L = 45\mu H$ corresponds to 5 MHz

An external clock signal can also be used as a frequency reference to the 8294; however, the levels are *not* compatible. The signal must be in the 1 MHz–6 MHz frequency range and must be connected to pins X1 and X2 by buffers with a suitable pull-up resistor to guarantee that a logic "1" is above 3.8 volts. The recommended connection is shown in Figure 18.

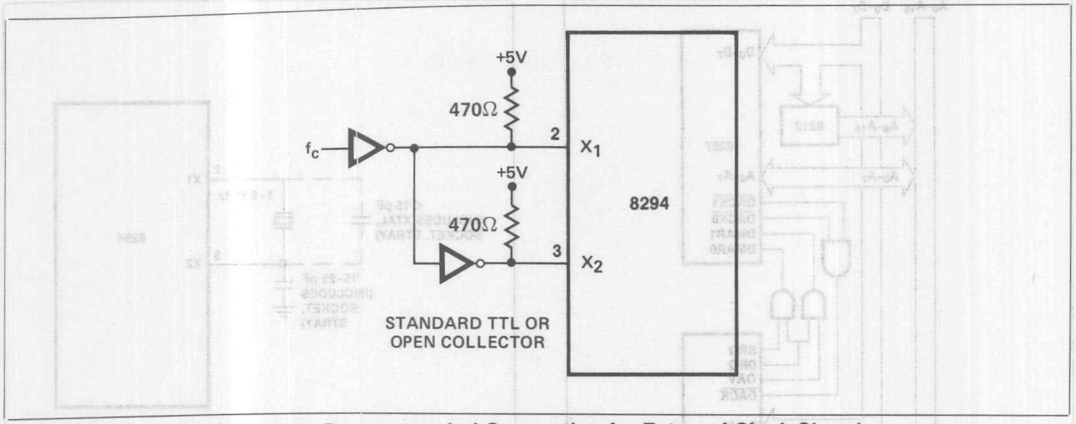


Figure 18. Recommended Connection for External Clock Signal

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias .... 0°C to 70°C
Storage Temperature .... −65°C to +150°C
Voltage on Any Pin With
Respect to Ground .... −0.5V to +7V
Power Dissipation .... 1.5 Watt

**NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. AND OPERATING CHARACTERISTICS (T_A = 0°C to 70°C, V_{CC} = +5V ± 10%, V_{SS} = 0V)

Symbol	Parameter	Limits Min.	Typ.	Max.	Unit	Test Conditions
V_{IL}	Input Low Voltage (All Except X_1, X_2, $\overline{\text{RESET}}$)	−0.5		0.8	V	
V_{IL1}	Input Low Voltage (X_1, X_2, $\overline{\text{RESET}}$)	−0.5		0.6	V	
V_{IH}	Input High Voltage (All Except X_1, X_2, $\overline{\text{RESET}}$)	2.2		V_{CC}	V	
V_{IH1}	Input High Voltage (X_1, X_2, $\overline{\text{RESET}}$)	3.8		V_{CC}	V	
V_{OL}	Output Low Voltage (D_0–D_7)			0.45	V	$I_{OL} = 2.0$ mA
V_{OL1}	Output Low Voltage (All Other Outputs)			0.45	V	$I_{OL} = 1.6$ mA
V_{OH}	Output High Voltage (D_0–D_7)	2.4			V	$I_{OH} = -400\,\mu A$
V_{OH1}	Output High Voltage (All Other Outputs)	2.4			V	$I_{OH} = -50\,\mu A$
I_{IL}	Input Leakage Current ($\overline{RD}$, $\overline{WR}$, $\overline{CS}$, $\overline{A_0}$)			±10	μA	$V_{SS} \leq V_{IN} \leq V_{CC}$
I_{OFL}	Output Leakage Current (D_0–D_7, High Z State)			±10	μA	$V_{SS} + 0.45 \leq V_{OUT} \leq V_{CC}$
I_{DD}	V_{DD} Supply Current		5	15	mA	
$I_{DD} + I_{CC}$	Total Supply Current		60	125	mA	
I_{LI}	Low Input Load Current (Pins 24, 27–38)			0.5	mA	$V_{IL} = 0.8V$
I_{LI1}	Low Input Load Current ($\overline{\text{RESET}}$)			0.2	mA	$V_{IL} = 0.8V$
I_{IH}	Input High Leakage Current (Pins 24, 27-38)			100	μA	$V_{IN} = V_{CC}$
C_{IN}	Input Capacitance			10	pF	
$C_{I/O}$	I/O Capacitance			20	pF	

A.C. CHARACTERISTICS ($T_A = 0°C$ to $70°C$, $V_{CC} = V_{DD} = +5V \pm 10\%$, $V_{SS} = 0V$)

DBB READ

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AR}	$\overline{CS}$, A_0 Setup to $\overline{RD}\downarrow$	0		ns	
t_{RA}	$\overline{CS}$, A_0 Hold After $\overline{RD}\uparrow$	0		ns	
t_{RR}	$\overline{RD}$ Pulse Width	250		ns	
t_{AD}	$\overline{CS}$, A_0 to Data Out Delay		225	ns	$C_L = 150\,pF$
t_{RD}	$\overline{RD}\downarrow$ to Data Out Delay		225	ns	$C_L = 150\,pF$
t_{DF}	$\overline{RD}\uparrow$ to Data Float Delay		100	ns	
t_{CY}	Cycle Time	2.5	15	μs	6 MHz Crystal

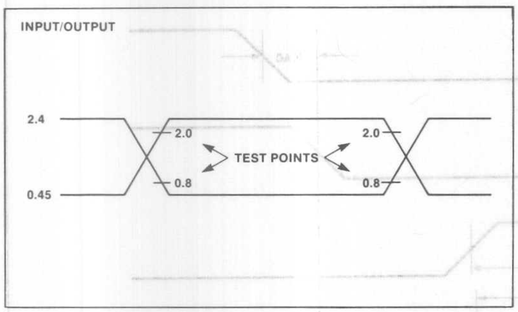
DBB WRITE

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	$\overline{CS}$, A_0 Setup to $\overline{WR}\downarrow$	0		ns	
t_{WA}	$\overline{CS}$, A_0 Hold After $\overline{WR}\uparrow$	0		ns	
t_{WW}	$\overline{WR}$ Pulse Width	250		ns	
t_{DW}	Data Setup to $\overline{WR}\uparrow$	150		ns	
t_{WD}	Data Hold to $\overline{WR}\uparrow$	0		ns	

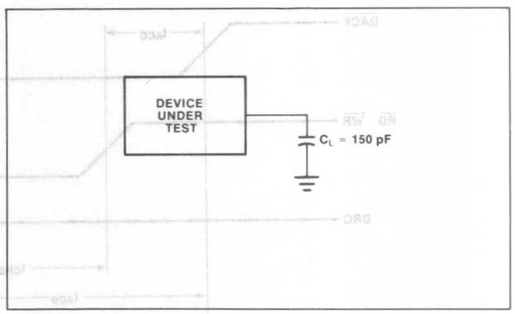
DMA AND INTERRUPT TIMING

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{ACC}	$\overline{DACK}$ Setup to Control	0		ns	
t_{CAC}	$\overline{DACK}$ Hold After Control	0		ns	
t_{ACD}	$\overline{DACK}$ to Data Valid		225	ns	$C_L = 150\,pF$
t_{CRQ}	Control L.E. to DRQ T.E.		200	ns	
t_{CI}	Control T.E. to Interrupt T.E.		$t_{CY} + 500$	ns	

A.C. TESTING INPUT, OUTPUT WAVEFORM



A.C. TESTING LOAD CIRCUIT



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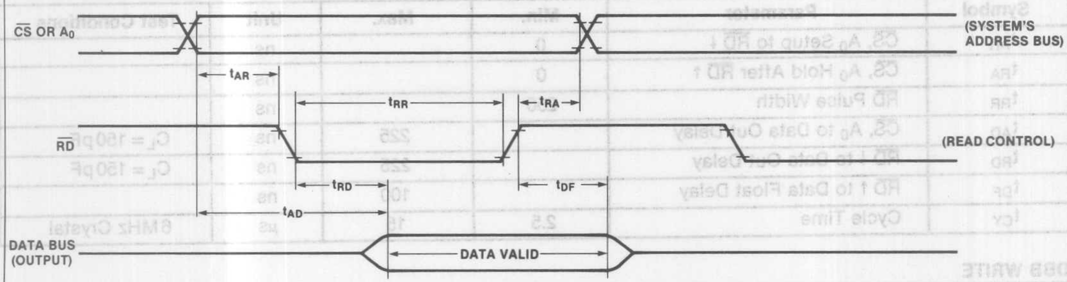
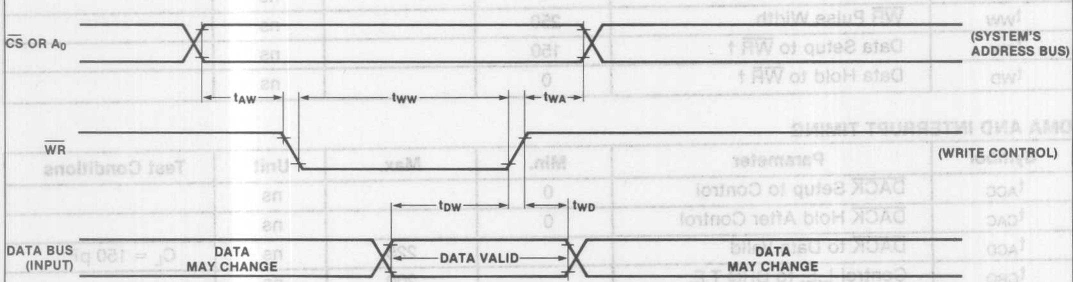
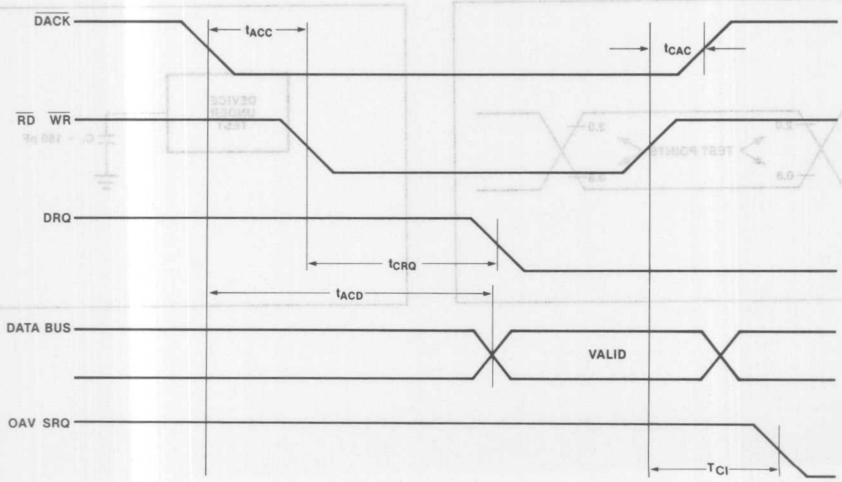
READ OPERATION—OUTPUT BUFFER REGISTER



WRITE OPERATION—INPUT BUFFER REGISTER



DMA AND INTERRUPT TIMING



intel®

8295
DOT MATRIX PRINTER CONTROLLER

- Interfaces Dot Matrix Printers to MCS-48™, MCS-80/85™, MCS-86™ Systems
- 40 Character Buffer On Chip
- Serial or Parallel Communication with Host
- DMA Transfer Capability
- Programmable Character Density (10 or 12 Chararcters/Inch)
- Programmable Print Intensity
- Single or Double Width Printing
- Programmable Multiple Line Feeds
- 3 Tabulations
- 2 General Purpose Outputs

The Intel® 8295 Dot Matrix Printer Controller provides an interface for microprocessors to the LRC 7040 Series dot matrix impact printers. It may also be used as an interface to other similar printers.

The chip may be used in a serial or parallel communication mode with the host processor. In parallel mode, data transfers are based on polling, interrupts, or DMA. Furthermore, it provides internal buffering of up to 40 characters and contains a 7×7 matrix character generator accommodating 64 ASCII characters.

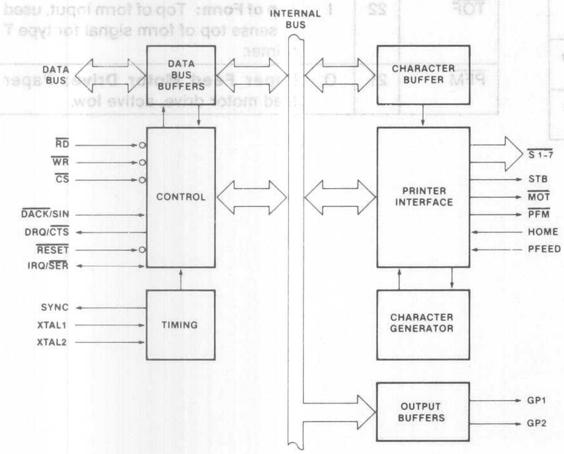


Figure 1. Block Diagram

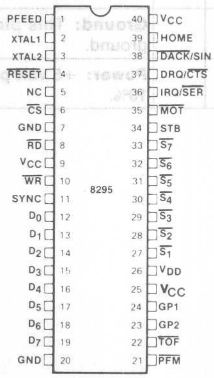


Figure 2. Pin Configuration

Table 1. Pin Description

Symbol	Pin No.	Type	Name and Function
PFEED	1	I	**Paper Feed:** Paper feed input switch.
XTAL1 XTAL2	2 3	I	**Crystal:** Inputs for a crystal to set internal oscillator frequency. For proper operation use 6 MHz crystal.
$\overline{\text{RESET}}$	4	I	**Reset:** Reset input, active low. After reset the 8295 will be set for 12 characters/inch single width printing, solenoid strobe at 320 msec.
NC	5		**No Connection:** No connection or tied high.
$\overline{\text{CS}}$	6	I	**Chip Select:** Chip select input used to enable the RD and WR inputs except during DMA.
GND	7		**Ground:** This pin must be tied to ground.
$\overline{\text{RD}}$	8	I	**Read:** Read input which enables the master CPU to read data and status. In the serial mode this pin must be tied to V_{CC}.
V_{CC}	9		**Power:** +5 volt power input: +5V ± 10%.
$\overline{\text{WR}}$	10	I	**Write:** Write input which enables the master CPU to write data and commands to the 8295. In the serial mode this pin must be tied to V_{SS}.
SYNC	11	O	**Sync:** 2.5 μs clock output. Can be used as a strobe for external circuitry.
D_0 D_1 D_2 D_3 D_4 D_5 D_6 D_7	12 13 14 15 16 17 18 19	I/O	**Data Bus:** Three-state bidirectional data bus buffer lines used to interface the 8295 to the host processor in the parallel mode. In the serial mode D_0—D_2 sets up the baud rate.
GND	20		**Ground:** This pin must be tied to ground.
V_{CC}	40		**Power:** +5 volt power input: +5 ± 10%.

Symbol	Pin No.	Type	Name and Function
HOME	39	I	**Home:** Home input switch, used by the 8295 to detect that the print head is in the home position.
$\overline{\text{DACK}}$/SIN	38	I	**DMA Acknowledge/Serial Input:** In the parallel mode used as DMA acknowledgment; in the serial mode, used as input for data.
DRQ/$\overline{\text{CTS}}$	37	O	**DMA Request/Clear to Send:** In the parallel mode used as DMA request output pin to indicate to the 8257 that a DMA transfer is requested; in the serial mode used as clear-to-send signal.
IRQ/$\overline{\text{SER}}$	36	O	**Interrupt Request/Serial Mode:** In parallel mode it is an interrupt request input to the master CPU; in serial mode it should be strapped to V_{SS}.
$\overline{\text{MOT}}$	35	O	**Motor:** Main motor drive, active low.
STB	34	O	**Solenoid Strobe:** Solenoid strobe output. Used to determine duration of solenoids activation.
$\overline{S_7}$ $\overline{S_6}$ $\overline{S_5}$ $\overline{S_4}$ $\overline{S_3}$ $\overline{S_2}$ $\overline{S_1}$	33 32 31 30 29 28 27	O	**Solenoid:** Solenoid drive outputs; active low.
V_{DD}	26		**Power:** +5V power input (+5V ± 10%). Low power standby pin.
V_{CC}	25		**Power:** Tied high.
GP1 GP2	24 23	O O	**General Purpose:** General purpose output pins.
$\overline{\text{TOF}}$	22	I	**Top of Form:** Top of form input, used to sense top of form signal for type T printer.
$\overline{\text{PFM}}$	21	O	**Paper Feed Motor Drive:** Paper feed motor drive, active low.

FUNCTIONAL DESCRIPTION

The 8295 interfaces microcomputers to the LRC 7040 Series dot matrix impact printers, and to other similar printers. It provides internal buffering of up to 40 characters. Printing begins automatically when the buffer is full or when a carriage return character is received. It provides a modified 7x7 matrix character generator. The character set includes 64 ASCII characters.

Communication between the 8295 and the host processor can be implemented in either a serial or parallel mode. The parallel mode allows for character transfers into the buffer via DMA cycles. The serial mode features selectable data rates from 110 to 4800 baud.

The 8295 also offers two general purpose output pins which can be set or cleared by the host processor. They can be used with various printers to implement such functions as ribbon color selection, enabling form release solenoid, and reverse document feed.

COMMAND SUMMARY

Hex Code	Description
00	Set GP1. This command brings the GP1 pin to a logic high state. After power on it is automatically set high.
01	Set GP2. Same as the above but for GP2.
02	Clear GP1. Sets GP1 pin to logic low state, inverse of command 00.
03	Clear GP2. Same as above but for GP2. Inverse command 01.
04	Software Reset. This is a pacify command. This command is not effective immediately after commands requiring a parameter, as the Reset command will be interpreted as a parameter.
05	Print 10 characters/in. density.
06	Print 12 characters/in. density.
07	Print double width characters. This command prints characters at twice the normal width, that is, at either 17 or 20 characters per line.
08	Enable DMA mode; must be followed by two bytes specifying the number of data characters to be fetched. Least significant byte accepted first.
09	Tab character.
0A	Line feed.
0B	Multiple Line Feed; must be followed by a byte specifying the number of line feeds.
0C	Top of Form. Enables the line feed output until the Top of Form input is activated.
0D	Carriage Return. Signifies end of a line and enables the printer to start printing.
0E	Set Tab #1, followed by tab position byte.
0F	Set Tab #2, followed by tab position byte. Should be greater than Tab #1.
10	Set Tab #3, followed by tab position byte. Should be greater than Tab #2.
11	Print Head Home on Right. On some printers the print head home position is on the right. This command would enable normal left to right printing with such printers.
12	Set Strobe Width; must be followed by strobe width selection byte. This command adjusts the duration of the strobe activation.

PROGRAMMABLE PRINTING OPTIONS

CHARACTER DENSITY

The character density is programmable at 10 or 12 characters/inch (32 or 40 characters/line). The 8295 is automatically set to 12 characters/inch at power-up. Invoking the Print Double-Width command halves the character density (5 or 6 characters/inch). The 10 char/in or 12 char/in command must be re-issued to cancel the Double-Width mode. Different character density modes may not be mixed within a single line of printing.

PRINT INTENSITY

The intensity of the printed characters is determined by the amount of time during which the solenoid is on. This on-time is programmable via the Set Strobe-Width command. A byte following this command sets the solenoid on-time according to Table 2. Note that only the three least significant bits of this byte are important.

Table 2. Solenoid On-Time

D7—D3	D2	D1	D0	Solenoid On (microsec)
x	0	0	0	200
x	0	0	1	240
x	0	1	0	280
x	0	1	1	320
x	1	0	0	360
x	1	0	1	400
x	1	1	0	440
x	1	1	1	480

TABULATIONS

Up to three tabulation positions may be specified with the 8295. The column position of each tabulation is selected by issuing the Set Tab commands, each fol-

tions will then remain valid until new Set Tab commands are issued.

Sending a tab character (09H) will automatically fill the character buffer with blanks up to the next tab position. The character sent immediately after the tab character will thus be stored and printed at that position.

CPU TO 8295 INTERFACE

Communication between the CPU and the 8295 may take place in either a serial or parallel mode. However, the selection of modes is inherent in the system hardware; it is not software programmable. Thus, the two modes cannot be mixed in a single 8295 application.

PARALLEL INTERFACE

Two internal registers on the 8295 are addressable by the CPU: one for input, one for output. The following table describes how these registers are accessed.

$\overline{RD}$	$\overline{WR}$	$\overline{CS}$	Register
1	0	0	Input Data Register
0	1	0	Output Status Register

Input Data Register—Data written to this register is interpreted in one of two ways, depending on how the data is coded.

1. A command to be executed (0XH or 1XH).
2. A character to be stored in the character buffer for printing (2XH, 3XH, 4XH, or 5XH). See the character set, Table 2.

Output Status Register—8295 status is available in this register at all times.

STATUS BIT:	7	6	5	4	3	2	1	0
FUNCTION:	x	x	PA	DE	x	x	IBF	x

PA—Parameter Required; PA = 1 indicates that a command requiring a parameter has been received. After the necessary parameters have been received by the 8295, the PA flag is cleared.

DE—DMA Enabled; DE = 1 whenever the 8295 is in DMA mode. Upon completion of the required DMA transfers, the DE flag is cleared.

IBF—Input Buffer Full; IBF = 1 whenever data is written to the Input Data Register. No data should be written to the 8295 when IBF = 1.

A flow chart describing communication with the 8295 is shown in Figure 3.

The interrupt request output (IRQ, Pin 36) is available on the 8295 for interrupt driven systems. This output is asserted true whenever the 8295 is ready to receive data.

To improve bus efficiency and CPU overhead, data may be transferred from main memory to the 8295 via DMA cycles. Sending the Enable DMA command (08H) activates the DMA channel of the 8295. This command must be followed by two bytes specifying the length of the data string to be transferred (least significant byte first). The 8295 will then assert the required DMA requests to tion. Figure 4 shows a block diagram of the 8295 in DMA mode.

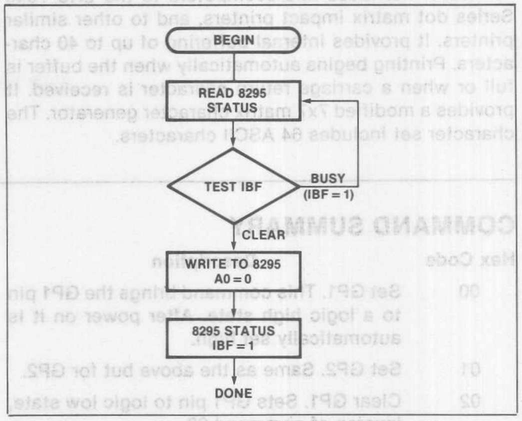


Figure 3. Host to 8295 Protocol Flowchart

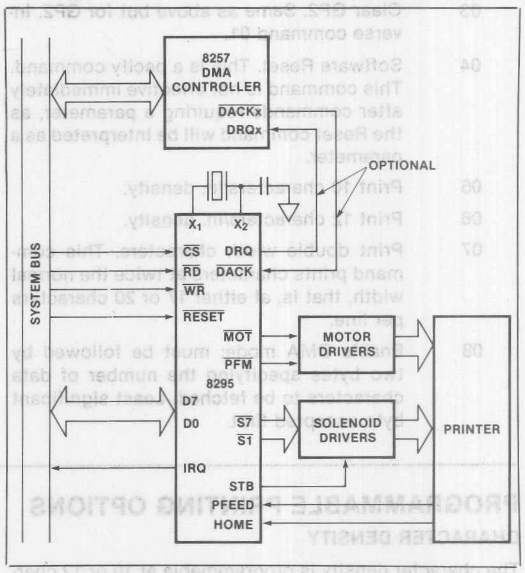


Figure 4. Parallel System Interface

Data transferred in the DMA mode may be either commands or characters or a mixture of both. The procedure is as follows:

1. Set up the 8257 DMA controller channel by sending a starting address and a block length.
2. Set up the 8295 by issuing the "Enable DMA" command (08H) followed by two bytes specifying the block length (least significant byte first).

The DMA enabled flag (DE) will be true until the assigned data transfer is completed. Upon completion of the transfer, the flag is cleared and the interrupt request (IRQ) signal is asserted. The 8295 then returns to the non-DMA mode of operation.

SERIAL INTERFACE

The 8295 may be hardware programmed to operate in a serial mode of communication. By connecting the IRQ/$\overline{SER}$ pin (pin 36) to logic zero, the serial mode is enabled immediately upon power-up. The serial Baud rate is also hardware programmable; by strapping pins 14, 13, and 12 according to Table 3, the rate is selected. $\overline{CS}$, $\overline{RD}$, and $\overline{WR}$ must be strapped as shown in Figure 5.

Table 3. Serial Baud Rate

Pin 14	Pin 13	Pin 12	Baud Rate
0	0	0	110
0	0	1	150
0	1	0	300
0	1	1	600
1	0	0	1200
1	0	1	2400
1	1	0	4800
1	1	1	4800

The serial data format is shown in Figure 5. The CPU should wait for a clear to send signal ($\overline{CTS}$) from the 8295 before sending data.

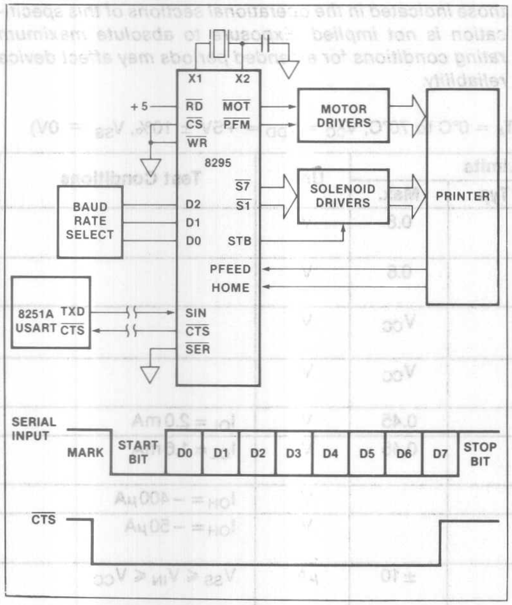


Figure 5. Serial Interface to UART (8251A)

8295 TO PRINTER INTERFACE

The strobe output signal of the 8295 determines the duration of the solenoid outputs, which hold the data to the printer. These solenoid outputs cannot drive the printer solenoids directly. They should be buffered through solenoid drivers as shown in Figure 6. Recommended solenoid and motor driver circuits may be found in the printer manufacturer's interface guide.

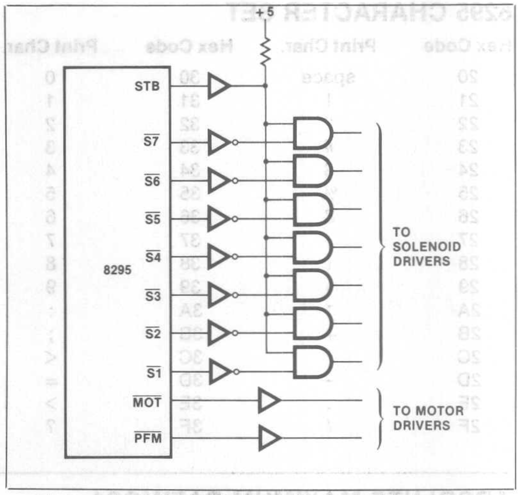


Figure 6. 8295 To Printer Solenoid Interface

OSCILLATOR AND TIMING CIRCUITS

The 8295's internal timing generation is controlled by a self-contained oscillator and timing circuit. A 6 MHz crystal is used to derive the basic oscillator frequency. The resident timing circuit consists of an oscillator, a state counter and a cycle counter as illustrated in Figure 7. The recommended crystal connection is shown in Figure 8.

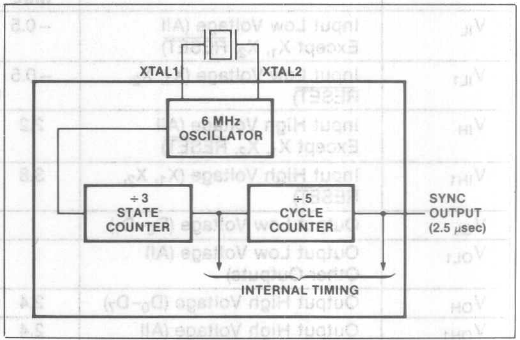


Figure 7. Oscillator Configuration

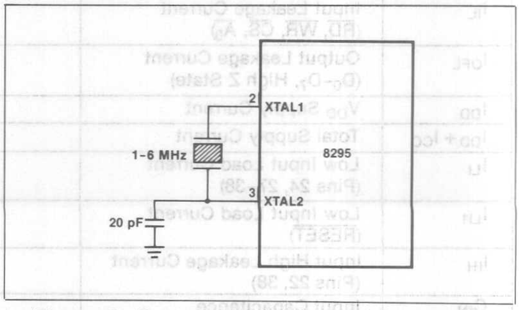


Figure 8. Recommended Crystal Connection

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8295 CHARACTER SET

Hex Code	Print Char.	Hex Code	Print Char.	Hex Code	Print Char.	Hex Code	Print Char.
20	space	30	0	40	@	50	P
21	!	31	1	41	A	51	Q
22	"	32	2	42	B	52	R
23	#	33	3	43	C	53	S
24	$	34	4	44	D	54	T
25	%	35	5	45	E	55	U
26	&	36	6	46	F	56	V
27	'	37	7	47	G	57	W
28	(	38	8	48	H	58	X
29	)	39	9	49	I	59	Y
2A	*	3A	:	5A	J	5A	Z
2B	+	3B	;	4B	K	5B	[
2C	,	3C	<	4C	L	5C	\
2D	−	3D	=	4D	M	5D	]
2E	.	3E	>	4E	N	5E	↑
2F	/	3F	?	4F	O	5F	—

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias . . . . 0°C to 70°C
Storage Temperature . . . . −65° to +150°C
Voltage on Any Pin With
  Respect to Ground . . . . −0.5V to +7V
Power Dissipation . . . . 1.5 Watt

**NOTICE: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.*

D.C. AND OPERATING CHARACTERISTICS ($T_A = 0°C$ to $70°C$, $V_{CC} = V_{DD} = +5V \pm 10\%$, $V_{SS} = 0V$)

Symbol	Parameter	Limits Min.	Typ.	Max.	Unit	Test Conditions
V_{IL}	Input Low Voltage (All Except X_1, X_2, $\overline{RESET}$)	−0.5		0.8	V	
V_{IL1}	Input Low Voltage (X_1, X_2, $\overline{RESET}$)	−0.5		0.6	V	
V_{IH}	Input High Voltage (All Except X_1, X_2, $\overline{RESET}$)	2.2		V_{CC}	V	
V_{IH1}	Input High Voltage (X_1, X_2, $\overline{RESET}$)	3.8		V_{CC}	V	
V_{OL}	Output Low Voltage (D_0-D_7)			0.45	V	$I_{OL} = 2.0 mA$
V_{OL1}	Output Low Voltage (All Other Outputs)			0.45	V	$I_{OL} = 1.6 mA$
V_{OH}	Output High Voltage (D_0-D_7)	2.4			V	$I_{OH} = -400 \mu A$
V_{OH1}	Output High Voltage (All Other Outputs)	2.4			V	$I_{OH} = -50 \mu A$
I_{IL}	Input Leakage Current ($\overline{RD}$, $\overline{WR}$, $\overline{CS}$, $\overline{A_0}$)			±10	μA	$V_{SS} \leq V_{IN} \leq V_{CC}$
I_{OFL}	Output Leakage Current (D_0-D_7, High Z State)			±10	μA	$V_{SS}+0.45 \leq V_{OUT} \leq V_{CC}$
I_{DD}	V_{DD} Supply Current		5	15	mA	
$I_{DD}+I_{CC}$	Total Supply Current		60	125	mA	
I_{LI}	Low Input Load Current (Pins 24, 27-38)			0.5	mA	$V_{IL} = 0.8V$
I_{LI1}	Low Input Load Current ($\overline{RESET}$)			0.2	mA	$V_{IL} = 0.8V$
I_{IH}	Input High Leakage Current (Pins 22, 38)			100	μA	$V_{IN} = V_{CC}$
C_{IN}	Input Capacitance			10	pF	
$C_{I/O}$	I/O Capacitance			20	pF	

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A.C. CHARACTERISTICS ($T_A = 0°C$ to $70°C$, $V_{CC} = V_{DD} = +5V \pm 10\%$, $V_{SS} = 0V$)

DBB READ

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AR}	$\overline{CS}$, A_0 Setup to $\overline{RD}$ ↓	0		ns	
t_{RA}	$\overline{CS}$, A_0 Hold After $\overline{RD}$ ↑	0		ns	
t_{RR}	$\overline{RD}$ Pulse Width	250		ns	
t_{AD}	$\overline{CS}$, A_0 to Data Out Delay		225	ns	$C_L = 150$ pF
t_{RD}	$\overline{RD}$ ↓ to Data Out Delay		225	ns	$C_L = 150$ pF
t_{DF}	$\overline{RD}$ ↑ to Data Float Delay		100	ns	
t_{CY}	Cycle Time	2.5	15	μs	

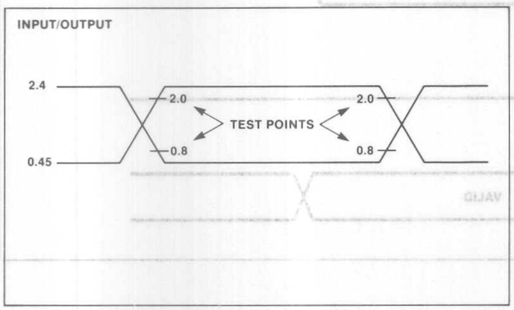
DBB WRITE

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{AW}	$\overline{CS}$, A_0 Setup to $\overline{WR}$ ↓	0		ns	
t_{WA}	$\overline{CS}$, A_0 Hold After $\overline{WR}$ ↑	0		ns	
t_{WW}	$\overline{WR}$ Pulse Width	250		ns	
t_{DW}	Data Setup to $\overline{WR}$ ↑	150		ns	
t_{WD}	Data Hold to $\overline{WR}$ ↑	0		ns	

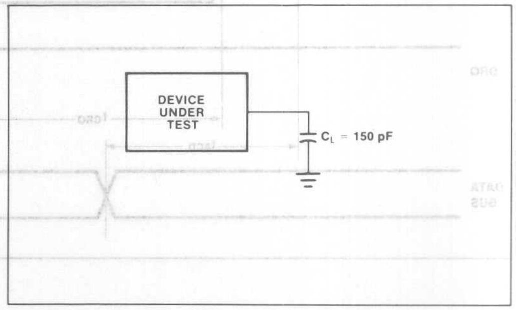
DMA AND INTERRUPT TIMING

Symbol	Parameter	Min.	Max.	Unit	Test Conditions
t_{ACC}	$\overline{DACK}$ Setup to Control	0		ns	
t_{CAC}	$\overline{DACK}$ Hold After Control	0		ns	
t_{CRQ}	$\overline{WR}$ to DRQ Cleared		200	ns	
t_{ACD}	$\overline{DACK}$ to Data Valid		225	ns	$C_L = 150$ pF

A.C. TESTING INPUT, OUTPUT WAVEFORM



A.C. TESTING LOAD CIRCUIT



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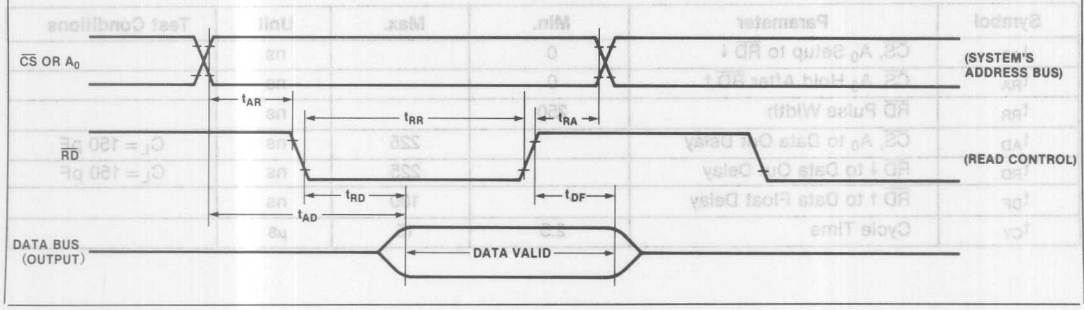
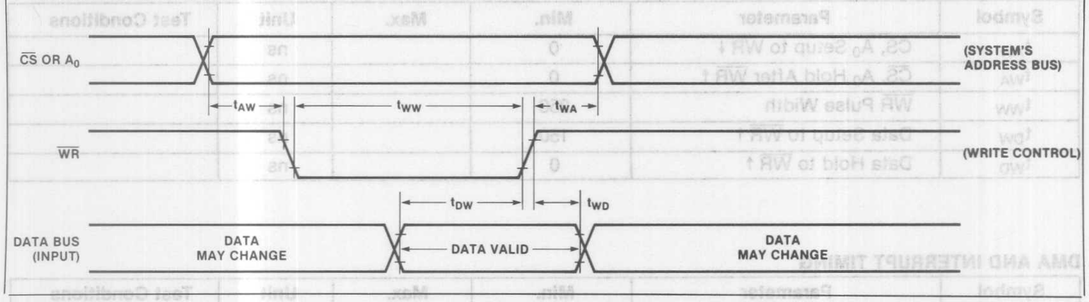
WAVEFORMS

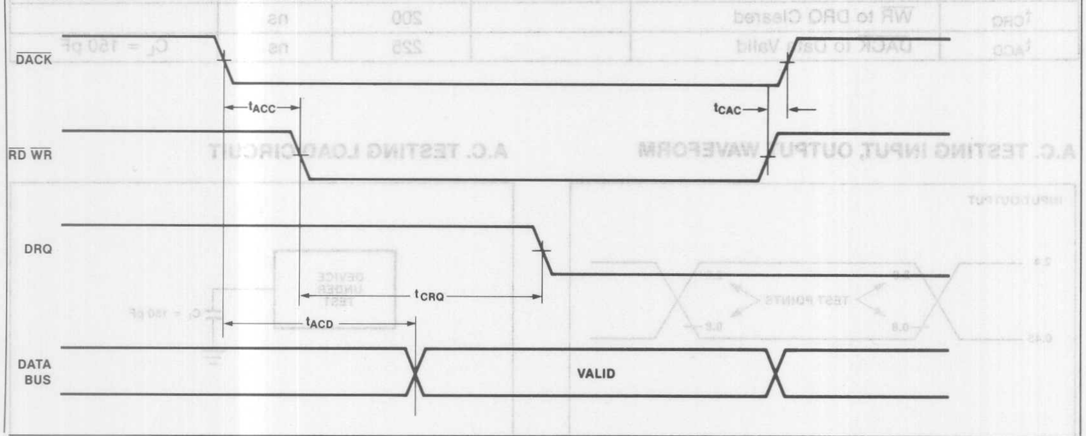
READ OPERATION—OUTPUT BUFFER REGISTER



WRITE OPERATION—INPUT BUFFER REGISTER

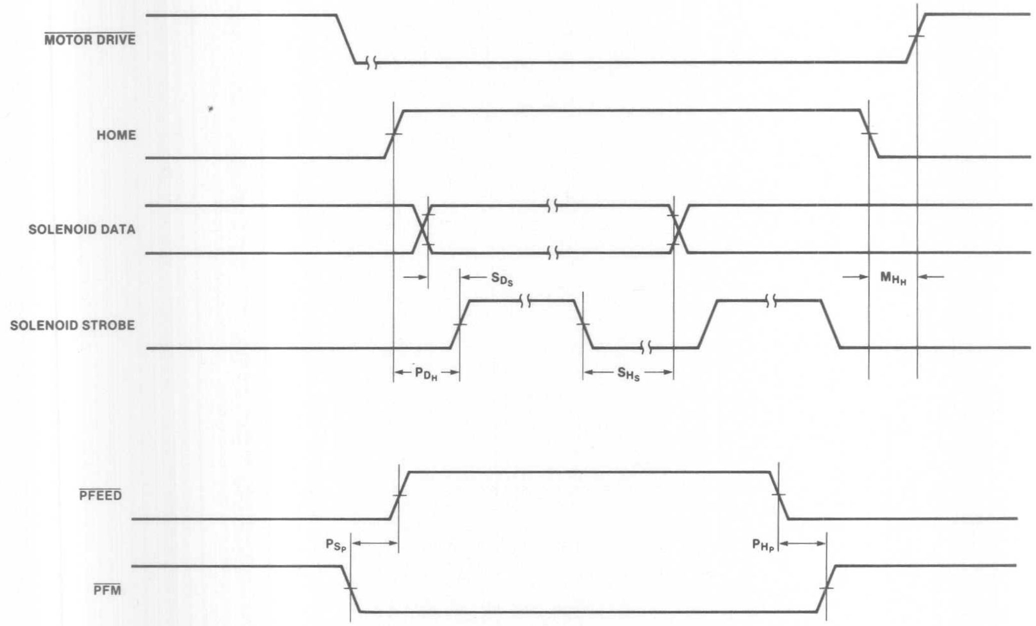


DMA AND INTERRUPT TIMING



WAVEFORMS (Continued)

PRINTER INTERFACE TIMING



Symbol	Parameter	Typical
P_{DH}	Print delay from home inactive	1.8 ms
S_{DS}	Solenoid data setup time before strobe active	25 μs
S_{HS}	Solenoid data hold after strobe inactive	>1 ms
M_{HA}	Motor hold time after home active	3.2 ms
P_{SP}	PFEED setup time after PFM active	58 ms
P_{HP}	PFM hold time after PFEED active	9.75 ms

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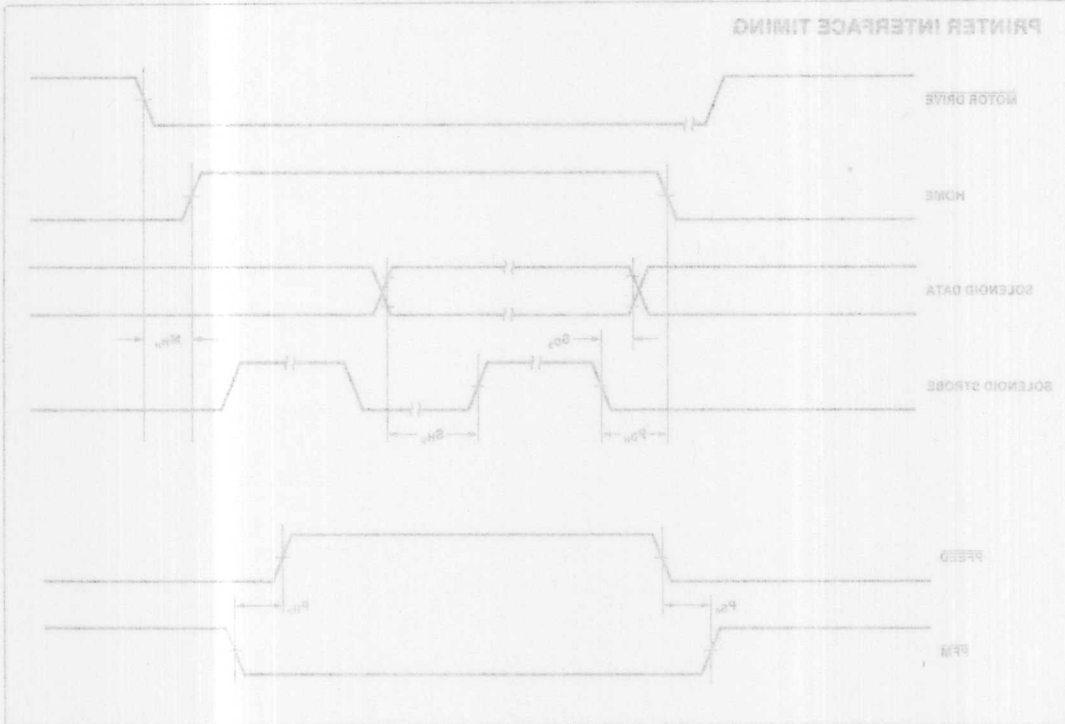
WAVEFORMS (Continued)



Symbol	Parameter	Typical
P_{DH}	Print delay from home inactive	1.8 ms
S_{DS}	Solenoid data setup time before strobe active	25 µs
S_{HS}	Solenoid data hold after strobe inactive	>1 ms
M_{HA}	Motor hold time after home active	3.2 ms
P_{SP}	PFEED setup time after PFM active	58 ms
P_{HP}	PFM hold time after PFEED active	9.75 ms

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System Support

ICE-41A™
UPI-41A IN-CIRCUIT EMULATOR

Extends Intellec microcomputer development system debug power to user configured system via external cable and 40-pin plug, replacing user UPI-41A™ devices

Emulates user system UPI-41A™ devices in real time

Allows user configured system to use static RAM memory for program debug

Provides hardware comparators for user designated break conditions

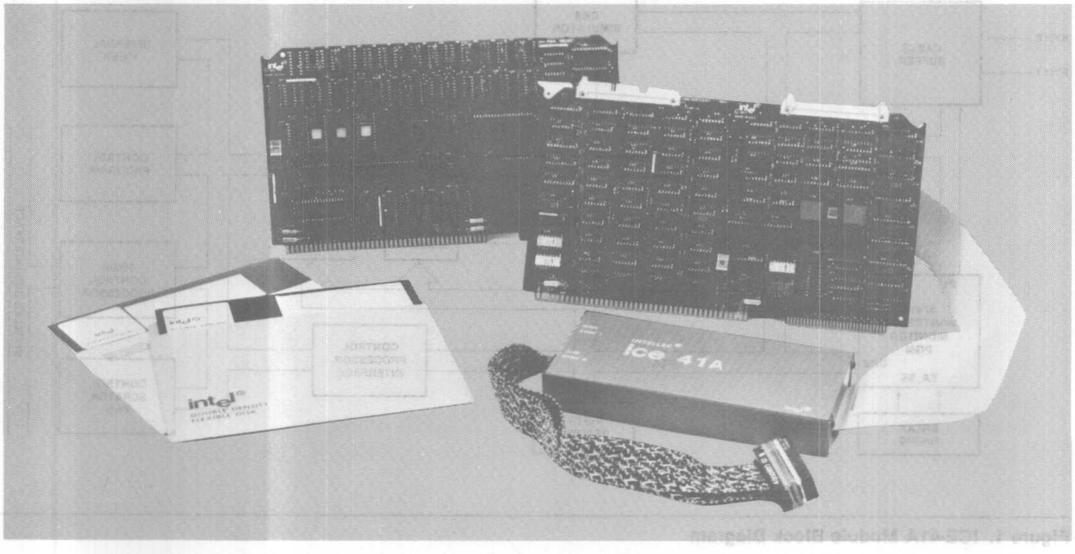
Eliminates need for extraneous debugging tools residing in user system

Collects address, data, and UPI-41A™ status information on machine cycles emulated

Provides capability to examine and alter UPI-41A™ registers, memory, and flag values, and to examine pin and port values

Integrates hardware and software efforts early in engineering cycle to save development time

The ICE-41A UPI-41A In-Circuit Emulator module is an Intellec system resident module that interfaces to any user configured UPI-41A system. The ICE-41A module interfaces with a UPI-41A pin-compatible plug which replaces the UPI-41A device in the system. With the ICE-41A plug in place, the designer has the capability to execute the system in real time while collecting up to 255 instruction cycles of real time trace data. In addition, he can single step the system program during execution. Static RAM memory is available through the ICE-41A module to store UPI-41A programs. The designer may display and alter the contents of program memory, internal UPI-41A registers and flags, and I/O ports. Powerful debug capability is extended into the UPI-41A system while ICE-41A debug hardware and software remain inside the Intellec system. Symbolic reference capability allows the designer to use symbols rather than absolute values when examining and modifying memory, registers, flags, and I/O ports in the system.



00804A

FUNCTIONAL DESCRIPTION

Debug Capability Inside User System

Intellec memory is used for the execution of the ICE-41A software. The Intellec CRT console and the file handling capabilities provide the designer with the ability to communicate with the ICE-41A module and display information on the operation of the prototype system. The ICE-41A module block diagram is shown in Figure 1.

Symbolic Debugging

Symbol Table — ICE-41A software allows the user to make symbolic references to I/O ports, memory addresses, and data in his program. The user symbol table which is generated along with the object file during a program assembly can be loaded to Intellec memory for access during emulation. The user may add to this symbol table any additional symbolic values for memory addresses, constants, or variables that he may find useful during system debugging. By referring to symbol memory addresses, the user can examine, change or break at the intended location. In addition, ICE-41A provides symbolic definition of all UPI-41A registers and flags.

Symbolic Reference — Symbolic reference is a great advantage to the system designer. He is no longer burdened with the need to recall or look up addresses of key locations in his program which can change with each assembly. Meaningful symbols from his source program can be used instead. For example, the command:

GO FROM .START TILL CODE. RSLT

begins execution of the program at the address referenced by the label START in the designer's assembly program. A breakpoint is set to occur the first time the microprocessor executes the program memory location referenced by RSLT. The designer does not have to be concerned with the physical locations of START and RSLT. The ICE-41A software driver supplies them automatically from information stored in the symbol table.

Memory Replacement

The 8741/8741A and 8041/8041A contain internal program and data memory. When the UPI-41A microcomputer is replaced by the ICE-41A socket in a system, the ICE-41A module supplies static RAM memory as a replacement for the internal microcomputer memory. The ICE-41A module has enough RAM memory available to emulate up to the total 1K control memory capability of the system.

Real-Time Trace

The ICE-41A module captures trace information while the designer is executing programs in real time. The instructions executed, program counter, port values for port 1 and port 2, and the values of selected UPI-41A status lines are stored for the last 255 instruction cycles executed. When retrieved for display, code is disassembled for user convenience. This provides data for determining how the user system was reacting prior to emulating break.

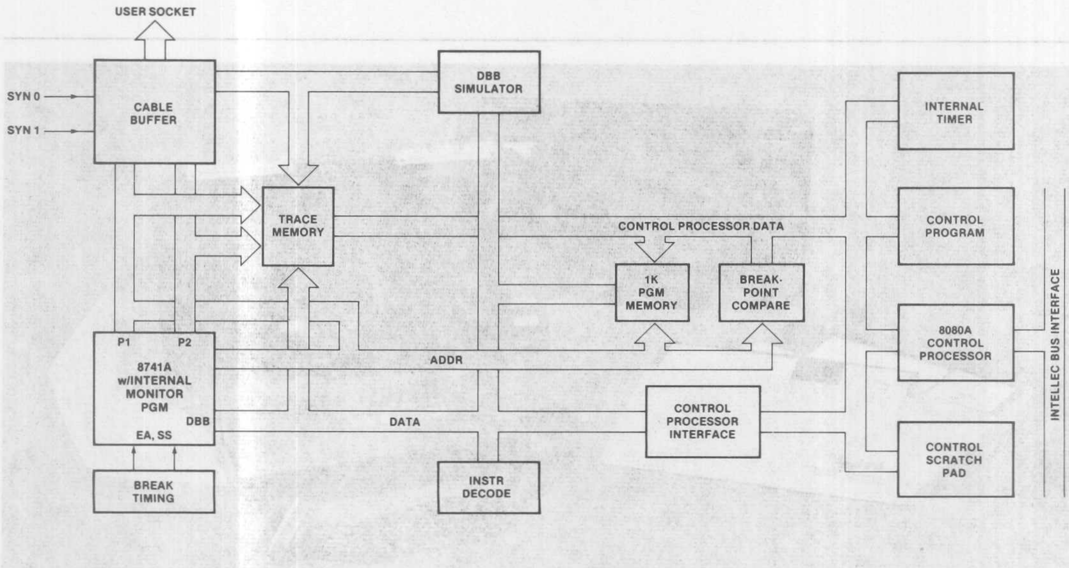


Figure 1. ICE-41A Module Block Diagram

Integrated Hardware/Software Development

The user prototype systems need no more than a UPI-41A socket and timing logic to begin integration of software and hardware development efforts. Through the ICE-41A module, Intellec system resources can be accessed to replace the prototype system. UPI-41A software development can proceed without the prototype hardware. Hardware designs can be tested using previously tested system software.

Hardware

The ICE-41A module is a microcomputer system utilizing Intel's UPI-41A microprocessor as its nucleus. This system communicates with the Intellec system 8080A processor via direct memory access. Host processor commands and ICE-41A status are interchanged through a DMA channel. ICE-41A hardware consists of two printed circuit boards, the controller board and the emulator board, which reside in the Intellec system chassis. A cable assembly interfaces the ICE-41A module to the user's UPI-41A system. The cable terminates in a UPI-41A pin-compatible plug which replaces any UPI-41A device in the user system.

Controller Board

The ICE-41A module interfaces to the Intellec systems as a peripheral device. The controller board receives commands from the Intellec system and responds through a DMA port. Three 10-bit hardware breakpoint registers are available which can be loaded by the user. While in emulation mode, a hardware comparator is constantly monitoring address lines for a match which will terminate an emulation. The controller board returns real-time trace data, UPI-41A registers, flag and port values, and status information to a control block in the Intellec system when emulation is terminated. This information is available to the user through the ICE-41A interrogation commands. Error conditions, when detected, are automatically displayed on the Intellec system console.

Emulator Board

The emulator board contains the 8741A and peripheral logic required to emulate the UPI-41A device in the user system. A 6 MHz clock drives the emulated UPI-41A device. This clock can be replaced with a user supplied TTL clock in the user system or can be strapped internally for 3 MHz operation.

Cable Card

The cable card is included for cable driving. It transmits address and data bus information to the user system through a 40-pin connector which plugs into the user system in the socket designed for the UPI-41A device.

Software

The ICE-41A software driver is a RAM-based program which provides the user with command language (see Table 1, Table 2, and Table 3) for defining breakpoints, initiating real-time emulation or single step operation, and interrogation and altering user system status recorded during emulation. The ICE-41A command language contains a broad range of modifiers which provide the user with maximum flexibility in defining the operation to be performed. The ICE-41A software driver is available on diskette and operates in 32K of Intellec RAM memory.

Command	Operation
Enable	Activates breakpoint and display registers for use with go and step commands.
Go	Initiates real-time emulation and allows user to specify breakpoints and data retrieval.
Step	Initiates emulation in single instruction increments. Each step is followed by register dump. User may optionally tailor other diagnostic activity to his needs.
Interrupt	Emulates user system interrupt

Table 1. ICE-41A Emulation Commands

Command	Operation
Display	Prints contents of memory, UPI-41A device registers, I/O ports, flags, pins, real-time trace data, symbol table, or other diagnostic data on list device.
Change	Alters contents of memory, register, output port, or flag. Sets or alters breakpoints and display registers.
Base	Establishes mode of display for output data.
Suffix	Establishes mode of display for input data.

Table 2. ICE-41A Interrogation Commands

Command	Operation
Load	Fetches user symbol table and object code from input device.
Save	Sends user symbol table and object code to output device.
Define	Enters symbol name and value to user symbol table.
Move	Moves block of memory data to another area of memory.
Print	Prints user specified portion of trace memory to selected list device.
List	Defines list device.
Exit	Returns program control to ISIS-II.
Evaluate	Converts expression to equivalent values in binary, octal, decimal, and hex.
Remove	Deletes symbols from symbol table.
Reset	Reinitializes ICE-41A hardware.

Table 3. ICE-41A Utility Commands

SPECIFICATIONS

ICE-41A Operating Environment

Required Hardware

Intellec microcomputer development system
System console
Intellec diskette operating system
ICE-41A module

Required Software

System monitor
ISIS-II
ICE-41A diskette-based software

System Clock

Crystal controlled 6.0 MHz or 3.0 MHz internal or user supplied TTL external

Physical Characteristics

Printed Circuit Boards

Width: 12.00 in. (30.48 cm)
Height: 6.75 in. (17.15 cm)
Depth: 0.50 in. (1.27 cm)
Weight: 8.00 lb (3.64 kg)

Cable Buffer Box

Width: 8.00 in. (20.32 cm)
Height: 4.00 in. (10.16 cm)
Depth: 1.25 in. (3.17 cm)
Flat Cable: 4.00 ft (121.92 cm)
User Cable: 15.00 in. (38.10 cm)

Electrical Characteristics

DC Power Requirements

$V_{CC} = +5V, \pm 5\%$
$I_{CC} = 10A$ max; 8A typ
$V_{DD} = +12V, \pm 5\%$
$I_{DD} = 100$ mA max; 60 mA typ
$V_{BB} = -10V$
$I_{BB} = 30$ mA

Input Impedance

@ ICE-41A user socket pins:
$V_{IL} = 0.8V$ max; $I_{IL} = 1.6$ mA
$V_{IH} = 2.0V$ min; $I_{IH} = 40\ \mu A$

@ Bus:
$V_{IL} = 0.8V$ max; $I_{IL} = 250\ \mu A$
$V_{IH} = 2.0V$ min; $V_{IH} = 20\ \mu A$

Output Impedance

@ P1, P2:
$V_{OL} = 0.5V$ max; $I_{OL} = 16$ mA
$V_{OH} = V_{CC}$ (10K pullup)

@ Bus:
$V_{OL} = 0.5V$ max; $I_{OL} = 25$ mA
$V_{OH} = 3.65V$ min; $I_{OH} = 1$ mA

Others

$V_{OL} = 0.5V$ max; $I_{OL} = 16$ mA
$V_{OH} = 2.4V$ max; $I_{OH} = 400\ \mu A$

Equipment Supplied

Controller board
Emulator board
Interface cables and buffer module
Operator's manual
ICE-41A diskette based software

Reference Manuals

9800465 — ICE-41A Operator's Manual (SUPPLIED)

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Part Number	Description
MDS-41A-ICE	UPI-41A (8741, 8041, 8741A, 8041A) CPU In-circuit emulator, cable assembly and interactive diskette software included

MULTI-ICE™ SOFTWARE
MULTIPLE-IN-CIRCUIT-EMULATOR

Facilitates software and hardware debugging of multi-processor systems.

Allows two In-Circuit Emulators to operate simultaneously in a single Intellec Microcomputer Development System.

Provides enhanced software features: Symbolic Display of Addresses, Macro Commands, Compound Commands, Software Synchronization of Processes, and INCLUDE File Capability.

Supports In-Circuit Emulator combinations, 85/85 Emulators, 85/49 Emulators (ICE-49™ Emulator supports the design using MCS-48™ chip family), and 85/41A Emulators.

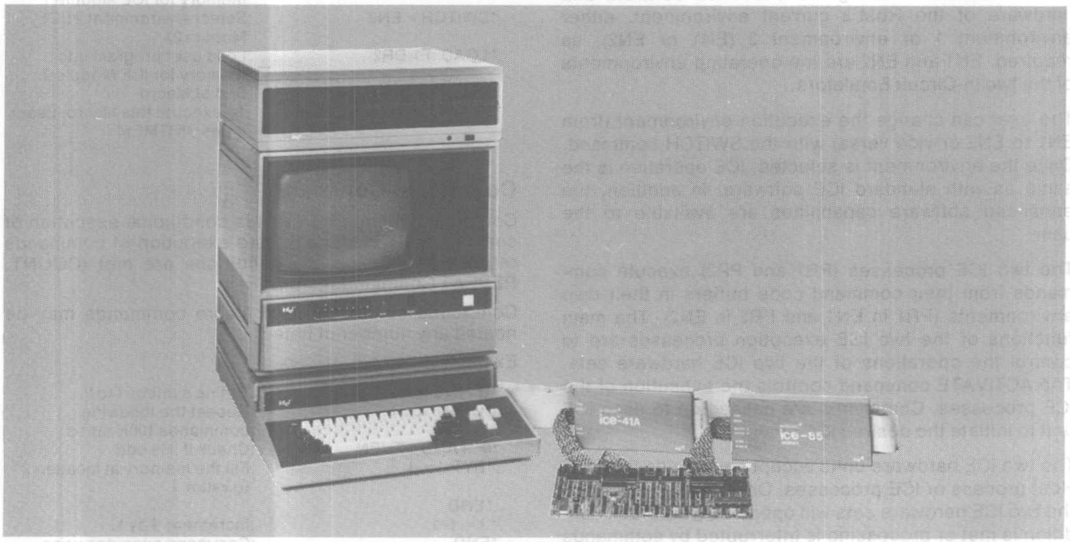
Functions under the supervision of ISIS-II Disk Operating System.

Supports ICE-85™ Emulator Hold Request/Hold Acknowledgement handshake while in both emulation and interrogation modes. (Can be used for Dynamic RAM refresh.)

Multi-ICE In-Circuit Emulator is a software product which allows two Intel In-Circuit Emulators to run simultaneously in a single Intellec Microcomputer Development System. Multi-ICE software used in lieu of the standard ICE software gives users full control of the Intellec Microcomputer Development System, and the two ICE modules for hardware and software debugging of multi-processor systems.

Enhancement features available with Multi-ICE software include a compound command capability which enables the user to "program" a diagnostic or exercise sequence. Also included are repeat and conditional execution of ICE commands, and the ability to invoke the macro commands by name.

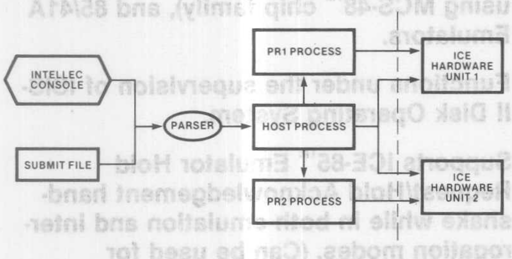
A special EPROM set for the ICE-85 Emulator is included. The new firmware will enable the ICE-85 Emulator to support Hold-Request and Hold-Acknowledgement hand-shake protocol both while in emulation and while in interrogation mode. This allows the ICE-85 Emulator to support typical dynamic RAM and DMA applications.



MULTI-ICE OPERATION

Multi-ICE software is a debug tool which allows two ICE emulators to begin and stop in sequence. Once started, two ICE emulators emulate simultaneously and independently. Thus, Multi-ICE software permits the debugging of asynchronous or synchronous multi-processor systems.

A conceptual model for the Multi-ICE software can be illustrated with the following block diagram.



Block Diagram of Multi-ICE™ Operation

There are three processes in the Multi-ICE environment: the Host process and the two ICE processes to control the two ICE hardware modules. The processor for these three processes is the microcomputer in the Intellec Microcomputer Development System. Only the Host process is active when Multi-ICE software is invoked. The Parser interfaces with the console, receives commands from the console or from a file, translates them into intermediate code, and loads the code into the Host command code buffer or ICE command code buffers.

The Host process executes commands from its command code buffer using the execution software and hardware of the Host's current environment, either environment 1 or environment 2 (EN1 or EN2), as required. EN1 and EN2 are the operating environments of the two In-Circuit Emulators.

The user can change the execution environment (from EN1 to EN2 or vice versa) with the SWITCH command. Once the environment is selected, ICE operation is the same as with standard ICE software. In addition, the enhanced software capabilities are available to the user.

The two ICE processes (PR1 and PR2) execute commands from their command code buffers in their own environments (PR1 in EN1 and PR2 in EN2). The main functions of the two ICE execution processes are to control the operations of the two ICE hardware sets. The ACTIVATE command controls the execution of the ICE processes. Commands are passed on to each ICE unit to initiate the desired ICE functions.

The two ICE hardware units accept commands from the Host process or ICE processes. Once emulations start, the two ICE hardware sets will operate until a break condition is met or processing is interrupted by commands from the ICE execution processes.

ENHANCED DIAGNOSTIC SOFTWARE FUNCTIONS

Single ICE™ Module Operation

Multi-ICE software can be used for single ICE operation. The operating procedures will be identical to the Multi-ICE operation. All the enhanced software functions will be available. The performance will be the same as if the standard ICE software is being used.

Symbolic Display of Addresses

The user has the option of displaying a 16-bit address in the form of a symbol name or line number plus a hex number offset.

Macro Command

A macro is a set of commands which is given a name. Thus, a group of commands which is executed frequently may be defined as a macro. Each time the user wants to execute that group of commands, he may just invoke the macro by typing a colon followed by the macro name. Up to ten parameters may be passed to the macro.

Macro commands may be defined at the beginning of a debug session and then can be used throughout the whole session. If the user wants to save the macros for later use, he may use the PUT command to save the macro on diskette, or the user may edit the macro file off-line using the Intellec text editor. Later, the user may use the INCLUDE command to bring in the macro definition file that he created.

Example:

```
*DEFINE MACRO INITMEM      ;This macro clears the
                           memory and then loads the
                           programs.
.*SWITCH = EN1             ;Select environment 1 (ICE
                           Module 1)
.*BYTE 0 TO 100=0          ;Initialize memory to 0.
.*LOAD :F1:DRIVER          ;Load user program into
                           memory for ICE Module 1.
.*SWITCH = EN2             ;Select environment 2 (ICE
                           Module 2)
.*LOAD :F1:DR2             ;Load user program into
                           memory for ICE Module 2.
.*EM                       ;End of Macro
*                          ;To execute this Macro, user
                           types :INITMEM
```

Compound Command

Compound commands provide conditional execution of commands (IF Command) and execution of commands repeatedly until certain conditions are met (COUNT, REPEAT Commands).

Compound commands and Macro commands may be nested any number of times.

Example:

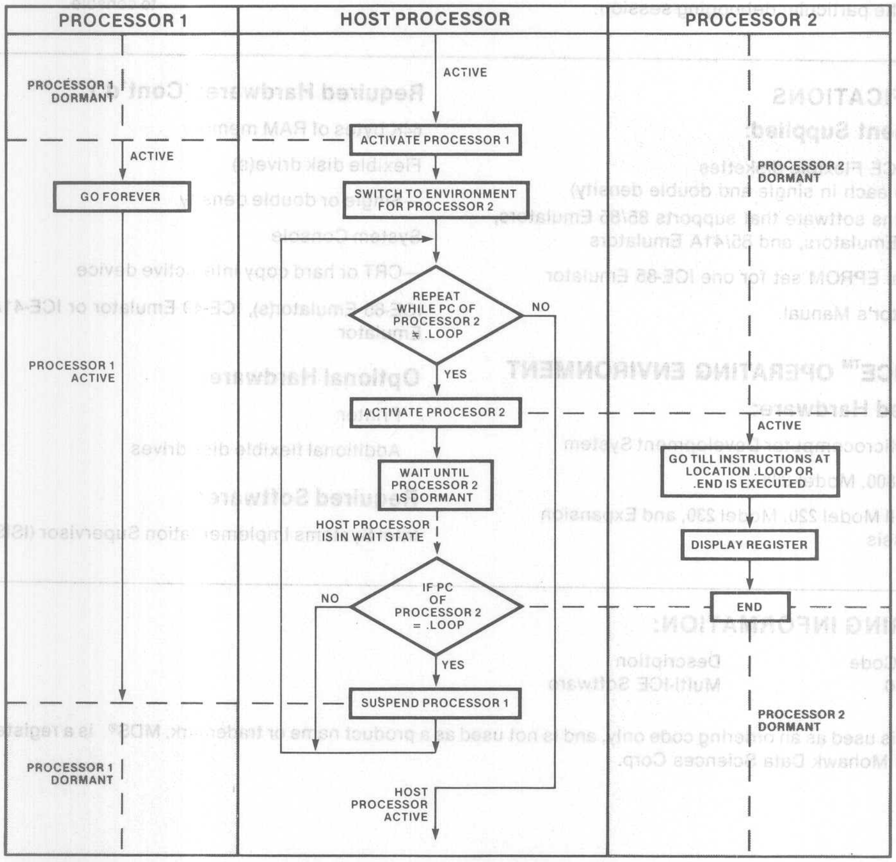
```
*DEFINE .I = 0             ;Define symbol .I to 0
*COUNT 100H                ;Repeat the following
                           commands 100H times.
.*IF .I AND 1 THEN         ;Check if .I is odd
..*BYT .I = .I             ;Fill the memory at location .I
                           to value .I
..*END
.*.I = .I+1                ;Increment .I by 1.
.*END                      ;Command executes upon
                           carriage-return after END
```

Software Synchronization of Processes

Up to three processes (Host, PR1 and PR2) can be active simultaneously in the system. An ICE process can be activated (ACTIVATE), suspended (SUSPEND), killed (KILL), or continued (CONTINUE). The Host process can wait for other processes to become dormant before it becomes active again. Through these synchronization commands, the user can create a system test file off-line yet be able to synchronize the three processes when the actual system test is executed.

Example:

The capability of the software synchronization commands is demonstrated by the following example. The flowchart shows the synchronization requirements. The program steps show the actual implementation.



Flowchart of the Example for Demonstrating Multi-ICE™ Synchronization Capability

```
*ACTIVATE PR1                ;Activate PR1
.*GO FROM 800                ;Start ICE Module 1
.*END                        ;End of Activate block
PR1 EMULATION BEGUN
*SWI=EN2                     ;Switch execution Environment to EN2
*REPEAT                      ;Repeat the following block of commands while PC is not equal to .Loop
.*WHILE PC < > .LOOP
.*ACT PR2                    ;Activate PR2
..*GO TILL .LOOP OR .END     ;Go till instruction at location .Loop or at location .END is executed
..*REGISTER                  ;Display the registers
..*END                       ;End of Activate block
.*WAIT PR2                   ;Wait until PR2 is dormant
.*IF PC=.LOOP THEN
..*SUSPEND PR1
..*END                       ;End of IF block
.*END                        ;End of REPEAT block
*
```

the file specified until the end of the file is encountered, at which point, input continues to be taken from the previous source. Nesting of INCLUDES is permitted. Since the command code file can be complex, the ability to edit offline becomes desirable. The INCLUDE command allows the user to pull in command code files and Macro commands created offline which can then be used for the particular debugging session.

```
*MAP 0 LENGTH 64K=USER   ;Contents of the file PROG1
                          are listed on screen as they
                          are executed.
*MAP IO 0 TO FF = USER
*SWITCH = EN2
*LOAD :F2:LED.HEX
 SWITCH = EN1            ;End of the file PROG1
*                        ;After the end of file is
                          reached, control is returned
                          to console.
```

SPECIFICATIONS

Equipment Supplied:

— Multi-ICE Flexible diskettes (one each in single and double density)
Contains software that supports 85/85 Emulators, 85/49 Emulators, and 85/41A Emulators

— Special EPROM set for one ICE-85 Emulator

— Operator's Manual

MULTI-ICE™ OPERATING ENVIRONMENT

Required Hardware:

Intellec Microcomputer Development System

—Model-800, Model-888

—Series II Model 220, Model 230, and Expansion Chassis

Required Hardware: (Cont'd.)

64K bytes of RAM memory

Flexible disk drive(s)

—Single or double density

System Console

—CRT or hard copy interactive device

ICE-85 Emulator(s), ICE-49 Emulator or ICE-41A Emulator

Optional Hardware:

Printer

Additional flexible disk drives

Required Software:

Intel Systems Implementation Supervisor (ISIS-II)

ORDERING INFORMATION:

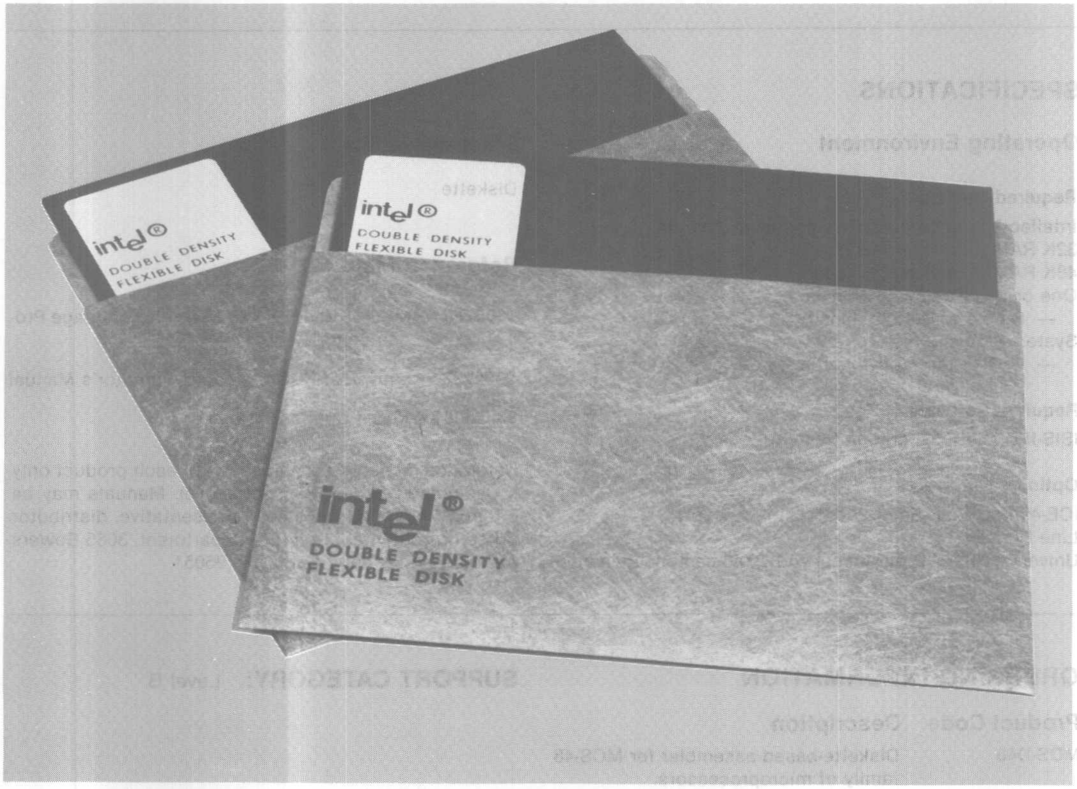
Product Code	Description
MDS*-350	Multi-ICE Software

*"MDS" is used as an ordering code only, and is not used as a product name or trademark. MDS® is a registered trademark of Mohawk Data Sciences Corp.

MCS™-48 DISKETTE-BASED SOFTWARE SUPPORT PACKAGE

- **Extends Intellec microcomputer development system to support MCS-48 development**
- **MCS-48 assembler provides conditional assembly and macro capability**
- **Takes advantage of powerful ISIS-II file handling and storage capabilities**
- **Provides assembler output in standard Intel hex format**

The MCS-48 assembler translates symbolic 8048 assembly language instructions into the appropriate machine operation codes, and provides both conditional and macroassembler programming. Output may be loaded either to an ICE-49 module for debugging or into a Universal PROM Programmer for 8748 PROM programming. The MCS-48 assembler operates under the ISIS-II operating system on Intellec Microcomputer Development systems.



FUNCTIONAL DESCRIPTION

The MCS-48 assembler translates symbolic 8048 assembly language instructions into the appropriate machine operation codes. The ability to refer to program addresses with symbolic names eliminates the errors of hand translation and makes it easier to modify programs when adding or deleting instructions. Conditional assembly permits the programmer to specify which portions of the master source document should be included or deleted in variations on a basic system design, such as the code required to handle optional external devices. Macro capability allows the programmer use of a single label to define a routine. The MCS-48 assembler will assemble the code required by the reserved routine whenever the macro label is inserted in the text. Output from the assembler is in standard Intel hex format. It may be either loaded directly to an in-circuit emulator (ICE-49) module for integrated hardware/software debugging, or loaded into a Universal PROM Programmer for 8748 PROM programming. A sample assembly listing is shown in Table 1.

Table 1. Sample MCS-48 Diskette-Based Assembly Listing

```
ISIS-II 8048 MACROASSEMBLER, V1.0                          PAGE 1

LOC    OBJ          SEQ          SOURCE STATEMENT

                     1   ;DECIMAL ADDITION ROUTINE. ADD BCD NUMBER
                     2   ;AT LOCATION 'BETA' TO BCD NUMBER AT 'ALPHA' WITH
                     3   ;RESULT IN 'ALPHA.' LENGTH OF NUMBER IS 'COUNT' DIGIT
                     4   ;PAIRS. (ASSUME BOTH BETA AND ALPHA ARE SAME LENGTH
                     5   ;AND HAVE EVEN NUMBER OF DIGITS OR MSD IS 0 IF
                     6   ;ODD)
                     7   INIT     MACRO    AUGND,ADDND,CNT
                     8            MOV      R0, #AUGND
                     9   L1:      MOV      R1, #ADDND
                    10            MOV      R2, #CNT
                    11            ENDM
                    12   ;
0001E               13   ALPHA    EQU      30
0028                14   BETA     EQU      40
0032                15   COUNT    EQU      5
0100                16            ORG      100H
                    17            INIT     ALPHA, BETA, COUNT
0100   B81E         18 +          MOV      R0, #ALPHA
0102   B928         19 + L1:      MOV      R1, #BETA
0104   BA32         20 +          MOV      R2, #COUNT
0106   97           21            CLR      C
0107   F0           22   LP:      MOV      A, @R0
0108   71           23            ADDC     A, @R1
0109   57           24            DA       A
010A   A1           25            MOV      @R0, A
010B   18           26            INC      R0
010C   19           27            INC      R1
010D   EA07         28            DJNZ     R2, LP
                                  END
USER SYMBOLS
ALPHA  0001E    BETA 0028    COUNT 0005    LP 0107
L1     0102

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V1.0             PAGE 1

SYMBOL CROSS REFERENCE

ALPHA   13#   17
BETA    14#   17
COUNT   15#   17
INIT     7#   17
L1      19#
LP      22#   28
```

SPECIFICATIONS

Operating Environment

Required Hardware

Intellec Microcomputer Development System
32K RAM (non-macro use)
48K RAM (use of macro facility)
One or two Floppy disk drives
— Single or Double density
System Console
— CRT or interactive hardcopy device

Required Software

ISIS-II Diskette Operating System

Optional Hardware

ICE-49 In-Circuit Emulator
Line Printer
Universal PROM Programmer with 8748 personality card

Shipping Media

Diskette

Reference Manuals

9800255 — MCS-48 and UPI-41 Assembly Language Programming Manual (SUPPLIED)

9800236 — Universal PROM Mapper Operator's Manual

9800306 — ISIS-II User's Guide

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Product Code	Description
MDS-D48	Diskette-based assembler for MCS-48 family of microprocessors.

SUPPORT CATEGORY: Level B

AFN-00819B

MODEL 230
INTELLEC® SERIES II
MICROCOMPUTER DEVELOPMENT SYSTEM

Complete microcomputer development center for Intel 80/85, 8086, and 8048 microprocessor families

LSI electronics board with CPU, RAM, ROM, I/O, and interrupt circuitry

64K bytes RAM memory

Self-test diagnostic capability

Eight-level nested, maskable priority interrupt system

Built-in interfaces for high speed paper tape reader/punch, printer, and universal PROM programmer

Integral CRT with detachable upper/lower case typewriter-style full ASCII keyboard

Powerful ISIS-II Diskette Operating System software with relocating macroassembler, linker, and locater

1 million bytes (expandable to 2.5M bytes) of diskette storage

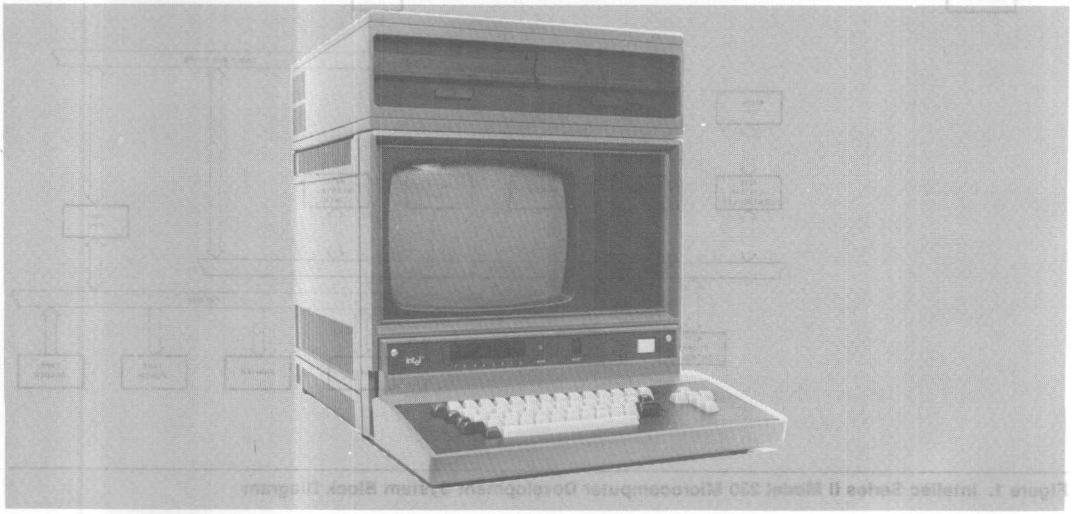
Supports PL/M and FORTRAN high level languages

Standard MULTIBUS™ multiprocessor and DMA capability

Compatible with standard Intellec/iSBC™ expansion modules

Software compatible with previous Intellec® systems

The Model 230 Intellec Series II Microcomputer Development System is a complete center for the development of microcomputer-based products. It includes a CPU, 64K bytes of RAM, 4K bytes of ROM memory, a 2000-character CRT, a detachable full ASCII keyboard, and dual double density diskette drives providing over 1 million bytes of on-line data storage. Powerful ISIS-II Diskette Operating System software allows the Model 230 to be used quickly and efficiently for assembling and/or compiling and debugging programs for Intel's 80/85, 8086, or 8048 microprocessor families without the need for handling paper tape. ISIS-II performs all file handling operations, leaving the user free to concentrate on the details of his own application. When used in conjunction with an optional in-circuit emulator (ICE) module, the Model 230 provides all the hardware and software development tools necessary for the rapid development of a microcomputer-based product.



FUNCTIONAL DESCRIPTION

Hardware Components

The Intellec Series II Model 230 is a packaged, highly integrated microcomputer development system consisting of a CRT chassis with a 6-slot cardcage, power supply, fans, cables, and five printed circuit cards. A separate, full ASCII keyboard is connected with a cable. A second chassis contains two floppy disk drives capable of double-density operation along with a separate power supply, fans, and cables for connection to the main chassis. A block diagram of the Model 230 is shown in Figure 1.

CPU Cards — The master CPU card contains its own microprocessor, memory, I/O, interrupt and bus interface circuitry fashioned from Intel's high technology LSI components. Known as the integrated processor board (IPB), it occupies the first slot in the cardcage. A second slave CPU card is responsible for all remaining I/O control including the CRT and keyboard interface. This card, mounted on the rear panel, also contains its own microprocessor, RAM and ROM memory, and I/O interface logic, thus, in effect, creating a dual processor environment. Known as the I/O controller (IOC), the slave CPU card communicates with the IPB over an 8-bit bidirectional data bus.

Memory and Control Cards — In addition, 32K bytes of RAM (bringing the total to 64K bytes) is located on a separate card in the main cardcage. Fabricated from Intel's 16K RAMs, the board also contains all necessary address decoding and refresh logic. Two additional boards in the cardcage are used to control the two double-density floppy disk drives.

Expansion — Two remaining slots in the cardcage are available for system expansion. Additional expansion of 4 slots can be achieved through the addition of an Intellec Series II expansion chassis.

System Components

The heart of the IPB is an Intel NMOS 8-bit microprocessor, the 8080A-2, running at 2.6 MHz. 32K bytes of RAM memory are provided on the board using Intel 16K RAMs. 4K of ROM is provided, preprogrammed with system bootstrap "self-test" diagnostics and the Intellec Series II System Monitor. The eight-level vectored priority interrupt system allows interrupts to be individually masked. Using Intel's versatile 8259 interrupt controller, the interrupt system may be user programmed to respond to individual needs.

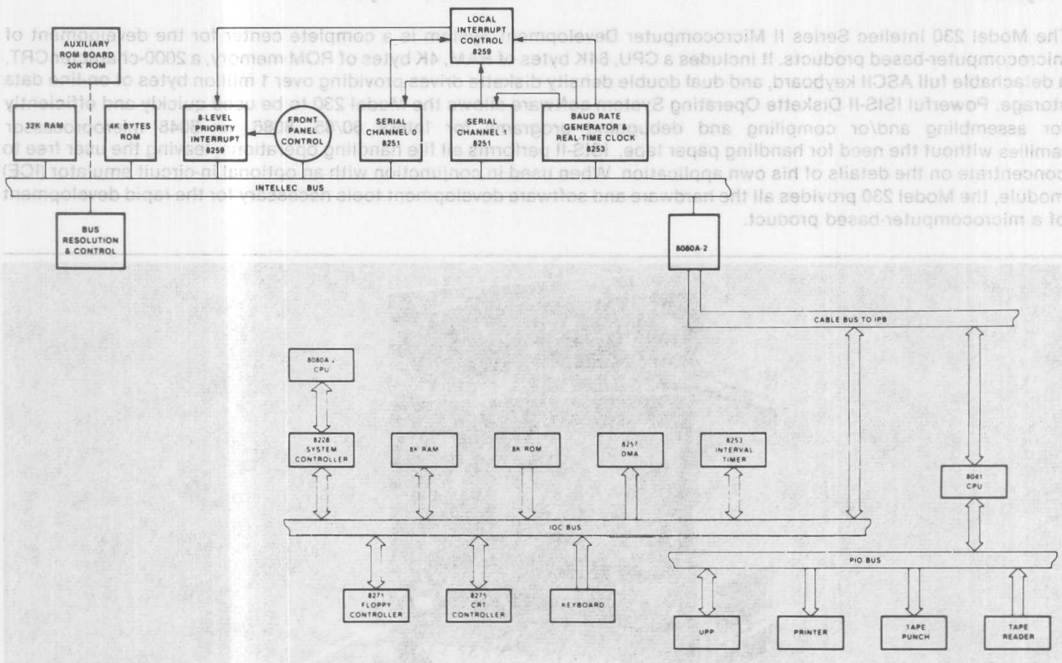


Figure 1. Intellec Series II Model 230 Microcomputer Development System Block Diagram

Input/Output

IPB Serial Channels — The I/O subsystem in the Model 230 consists of two parts: the IOC card and two serial channels on the IPB itself. Each serial channel is RS232 compatible and is capable of running asynchronously from 110 to 9600 baud or synchronously from 150 to 56K baud. Both may be connected to a user defined data set or terminal. One channel contains current loop adapters. Both channels are implemented using Intel's 8251 USART. They can be programmatically selected to perform a variety of I/O functions. Baud rate selection is accomplished progammatically through an Intel 8253 interval timer. The 8253 also serves as a real-time clock for the entire system. I/O activity through both serial channels is signaled to the system through a second 8259 interrupt controller, operating in a polled mode nested to the primary 8259.

IOC Interface — The remainder of system I/O activity takes place in the IOC. The IOC provides interface for the CRT, keyboard, and standard Intellec peripherals including printer, high speed paper tape reader/punch, and universal PROM programmer. The IOC contains its own independent microprocessor, also an 8080A-2. The CPU controls all I/O operations as well as supervising communications with the IPB. 8K bytes of ROM contain all I/O control firmware. 8K bytes of RAM are used for CRT screen refresh storage. These do not occupy space in Intellec Series II main memory since the IOC is a totally independent microcomputer subsystem.

Integral CRT

Display — The CRT is a 12-inch raster scan type monitor with a 50/60 Hz vertical scan rate and 15.5 kHz horizontal scan rate. Controls are provided for brightness and contrast adjustments. The interface to the CRT is provided through an Intel 8275 single chip programmable CRT controller. The master processor on the IPB transfers a character for display to the IOC, where it is stored in RAM. The CRT controller reads a line at a time into its line buffer through an Intel 8257 DMA controller and then feeds one character at a time to the character generator to produce the video signal. Timing for the CRT control is provided by an Intel 8253 interval timer. The screen display is formatted as 25 rows of 80 characters. The full set of ASCII characters are displayed, including lower case alphas.

Keyboard — The keyboard interfaces directly to the IOC processor via an 8-bit data bus. The keyboard contains an Intel UPI-41 Universal Peripheral Interface, which scans the keyboard, encodes the characters, and buffers the characters to provide N-key rollover. The keyboard itself is a high quality typewriter style keyboard containing the full ASCII character set. An upper/lower case switch allows the system to be used for document preparation. Cursor control keys are also provided.

Peripheral Interface

A UPI-41 Universal Peripheral Interface on the IOC board performs similar functions to the UPI-41 on the PIO board in the Model 210. It provides interface for other standard Intellec peripherals including a printer, high speed paper tape reader, high speed paper tape punch, and universal PROM programmer. Communication between the IPB and IOC is maintained over a separate 8-bit bidirectional data bus. Connectors for the four devices named above, as well as the two serial channels, are mounted directly on the IOC itself.

Control

User control is maintained through a front panel, consisting of a power switch and indicator, reset/boot switch, run/halt light, and eight interrupt switches and indicators. The front panel circuit board is attached directly to the IPB, allowing the eight interrupt switches to connect to the primary 8259, as well as to the Intellec Series II bus.

Diskette System

The Intellec Series II double density diskette system provides direct access bulk storage, intelligent controller, and two diskette drives. Each drive provides ½ million bytes of storage with a data transfer rate of 500,000 bits/second. The controller is implemented with Intel's powerful Series 3000 Bipolar Microcomputer Set. The controller provides an interface to the Intellec Series II system bus, as well as supporting up to four diskette drives. The diskette system records all data in soft sector format. The diskette system is capable of performing seven different operations: recalibrate, seek, format track, write data, write deleted data, read data, and verify CRC.

Diskette Controller Boards — The diskette controller consists of two boards, the channel board and the interface board. These two PC boards reside in the Intellec Series II system chassis and constitute the diskette controller. The channel board receives, decodes and responds to channel commands from the 8080A-2 CPU in the Model 230. The interface board provides the diskette controller with a means of communication with the diskette drives and with the Intellec system bus. The interface board validates data during reads using a cyclic redundancy check (CRC) polynomial and generates CRC data during write operations. When the diskette controller requires access to Intellec system memory, the interface board requests and maintains DMA master control of the system bus, and generates the appropriate memory command. The interface board also acknowledges I/O commands as required by the Intellec bus. In addition to supporting a second set of double density drives, the diskette controller may co-reside with the Intel single density controller to allow up to 2.5 million bytes of on-line storage.

MULTIBUS Capability

All Intellec Series II models implement the industry standard MULTIBUS. MULTIBUS enables several bus masters, such as CPU and DMA devices, to share the bus and memory by operating at different priority levels. Resolution of bus exchanges is synchronized by a bus clock signal derived independently from processor clocks. Read/write transfers may take place at rates up to 5 MHz. The bus structure is suitable for use with any Intel microcomputer family.

SPECIFICATIONS

Host Processor (IPB)

RAM — 64K (system monitor occupies 62K through 64K)
ROM — 4K (2K in monitor, 2K in boot/diagnostic)

Diskette System Capacity (Basic Two Drives)

Unformatted
Per Disk: 6.2 megabits
Per Track: 82.0 kilobits
Formatted
Per Disk: 4.1 megabits
Per Track: 53.2 kilobits

Diskette Performance

Diskette System Transfer Rate — 500 kilobits/sec
Diskette System Access Time
Track-to-Track: 10 ms
Head Settling Time: 10 ms
Average Random Positioning Time — 260 ms
Rotational Speed — 360 rpm
Average Rotational Latency — 83 ms
Recording Mode — M^2FM

Physical Characteristics

Width — 17.37 in. (44.12 cm)
Height — 15.81 in. (40.16 cm)
Depth — 19.13 in. (48.59 cm)
Weight — 73 lb (33 kg)

Keyboard
Width — 17.37 in. (44.12 cm)
Height — 3.0 in. (7.62 cm)
Depth — 9.0 in. (22.86 cm)
Weight — 6 lb (3 kg)

Dual Drive Chassis
Width — 16.88 in. (42.88 cm)
Height — 12.08 in. (30.68 cm)
Depth — 19.0 in. (48.26 cm)
Weight — 64 lb (29 kg)

Electrical Characteristics

DC Power Supply

Volts Supplied	Amps Supplied	Typical System Requirements
+ 5 ± 5%	30	14.25
+ 12 ± 5%	2.5	0.2
− 12 ± 5%	0.3	0.05
− 10 ± 5%	1.5	15
* + 15 ± 5%	1.5	1.3
* + 24 ± 5%	1.7	

*Not available on bus.

AC Requirements — 50/60 Hz, 115/230V AC

Environmental Characteristics

Operating Temperature — 0° to 35°C (95°F)

Equipment Supplied

Model 230 chassis
Integrated processor board (IPB)
I/O controller board (IOC)
32K RAM board
CRT and keyboard
Double density floppy disk controller (2 boards)
Dual drive floppy disk chassis and cables
2 floppy disk drives (512K byte capacity each)
ROM-resident system monitor
ISIS-II system diskette with MCS-80/MCS-85 macroassembler

Reference Manuals

9800558 — A Guide to Microcomputer Development Systems (SUPPLIED)

9800550 — Intellec Series II Installation and Service Guide (SUPPLIED)

9800306 — ISIS-II System User's Guide (SUPPLIED)

9800556 — Intellec Series II Hardware Reference Manual (SUPPLIED)

9800555 — Intellec Series II Hardware Reference Manual (SUPPLIED)

9800301 — 8080/8085 Assembly Language Programming Manual (SUPPLIED)

9800292 — ISIS-II 8080/8085 Assembler Operator's Manual (SUPPLIED)

9800605 — Intellec Series II Systems Monitor Source Listing (SUPPLIED)

9800554 — Intellec Series II Schematic Drawings (SUPPLIED)

Reference manuals are shipped with each product only if designated SUPPLIED (see above). Manuals may be ordered from any Intel sales representative, distributor office or from Intel Literature Department, 3065 Bowers Avenue, Santa Clara, California 95051.

ORDERING INFORMATION

Part Number	Description
MDS-230	Intellec Series II Model 230 microcomputer development system (110V/60 Hz)
MDS-231	Intellec Series II Model 230 microcomputer development system (220V/50 Hz)

intel®

iUP-200/iUP-201
UNIVERSAL PROM PROGRAMMERS

MAJOR iUP-200/iUP-201 FEATURES:

- **Serial interface to all INTELLEC® Development Systems**
- **Powerful PROM Programming Software utility (iPPS)**
- **Support for all Intel PROM families through multiple device Personality Modules**
- **iUP system self-tests plus device integrity checks**

ADDITIONAL iUP-201 FEATURES:

- **24-character alpha-numeric display**
- **Full hexadecimal plus 11-function keypads**
- **Off-line editing and device duplication**
- **16K bytes RAM expandable to 32K bytes**

The iUP-200 and iUP-201 Universal Prom Programmers provide programming and verification of data in all the Intel programmable ROMs (PROMs). They can also be used for programming the PROM memory portions of Intel's single-chip microcomputer and peripheral devices. When used with any INTELLEC Development System, the iUP-200 and iUP-201 provide on-line programming and verification with the aid of the Intel PROM Programming Software utility (iPPS). In addition, the iUP-201 supports off-line, stand-alone, program editing and PROM duplication. The iUP-200 is completely expandable to the iUP-201.

FUNCTIONAL DESCRIPTION

On-Line System

Hardware Components—The basic iUP-200 and iUP-201 consist of a free-standing unit that, when interfaced directly to any Intel Development System equipped with at least 64K bytes of user memory, provides "on-line" PROM programming and verification of Intel programmable devices. In addition, the units can read the contents of the ROM versions of these devices. Communication with the host is accomplished through a standard RS232C serial data link. A serial converter is needed when using the MDS-800 as a host system. These converters are available from other manufacturers. Each unit contains an 8085 CPU, selectable power supply, 2.3K bytes of static RAM, 8K bytes of pre-programmed EPROM, a programmable timer, and circuitry for interfacing to a Personality Module, keyboard, display, and host system. The pre-programmed EPROM contains the firmware needed for all iUP edit and control functions.

The interface between the iUP and the target PROM is accomplished using a family or single-device Personality Module. No additional sockets or adaptors are necessary. These Personality Modules are iUP front panel inserted units containing all the hardware and firmware necessary for programming either a family of Intel PROMs or a single Intel device. Figure 1 diagrams the on-line system data flow.

The iUP-201 will also accept Intel hexadecimal programs developed on a non-Intel Development System. Only a few keystrokes are required to download the program into iUP RAM for editing and loading into a PROM.

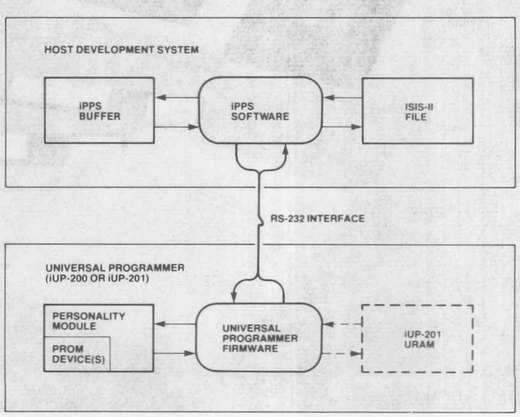
Software Components—The Intel PROM Programming Software utility (iPPS) is included with both the iUP-200 and iUP-201. Created to run on any INTELLEC Development System, iPPS provides user control of all reading, programming, and verification functions through an easy to use language driven interface. All iPPS commands, as well as program address and data information, are entered through the development system ASCII keyboard and displayed on the system CRT. These plain English commands allow the user to read and write data to or from any of three logical devices: the target PROM, the INTELLEC system memory, or a disk file system. Additional commands control iPPS program execution, display information and status, allow rearrangement of data from any of the three logical devices, and provide user assistance information in the form of a HELP command. Figure 2 summarizes these commands.

Loading programs into a PROM from INTELLEC system memory or directly from a disk file is accomplished under iPPS control. Access to the disk allows the user to create and manipulate data in a virtual buffer with an address range up to 16M. This large block of data can be formatted into different PROM word sizes for program storage into several different PROM types. In addition, a program from any of the three logical devices can be "interleaved" with a second program and entered into a specific target PROM or PROMs.

iPPS supports data manipulation in any Intel format: 8080 hexadecimal ASCII, 8080 absolute object, 8086 hexadecimal ASCII, 8086 absolute object, and 286 absolute object. Addresses and data can be displayed in one of several number bases including binary, octal, decimal, and hexadecimal. The user can easily change defaulted data formats as well as number bases.

iPPS requires that version 3.4 or later of Intel's ISIS-II Operating System be resident in INTELLEC Development System memory at the time of execution. The software is designed to run under control of ISIS "Submit Files" thereby freeing the user from repetitious command entry.

System Expansion—The iUP-200 can be easily expanded, by the user, for off-line operation. The Keyboard/Expansion Kit (iUP-PAK) is available from Intel or your local Intel Distributor.



AFN-02138A

Figure 1. On-Line System Data Flow

Program Control Group—Controls the program execution of iPPS.

EXIT	Exits iPPS and returns control to ISIS-II
<ESC>	Terminates current command
REPEAT	Repeats full execution of previous command
ALTER	Allows edit and re-execution of previous command

Utility Group—Displays user information, status, and sets default values.

DISPLAY	Displays PROM, Buffer, or File data on the console
PRINT	Prints PROM, Buffer or File data on a printer
HELP	Selectively displays user assistance information
MAP	Displays Buffer structure and status
BLANKCHECK	Checks for unprogrammed PROM
OVERLAY	Checks if non-blank PROM can be programmed
TYPE	Selects PROM type
INIT	Initializes the default number base and file type
WORKFILES	Specifies drive device for temporary work files

Buffer Group—Edits, modifies, and verifies data in the Buffer.

SUBSTITUTE	Examines and modifies Buffer data
LOADDATA	Loads a section of the buffer with a constant
VERIFY	Verifies data in PROM with Buffer data

Formatting Group—Permits rearrangement of data from PROM, Buffer, or File.

FORMAT	Interactively formats the Buffer, PROM, or File data and places the result in a workfile

Copy Group—Provides for variations of the general purpose COPY command.

COPY (File to PROM)	Programs PROM with data in a file on disk	
COPY (PROM to File)	Saves PROM data in file on disk	
COPY (Buffer to PROM)	Programs PROM device from Buffer	
COPY (PROM to Buffer)	Loads Buffer with data in PROM	
COPY (Buffer to File)	Saves Buffer in file on disk	
COPY (File to Buffer)	Loads Buffer from file on disk	
COPY (File to URAM)	Loads file data into iUP URAM	(iUP-201 only)
COPY (URAM to File)	Save iUP URAM data in a file	(iUP-201 only)
COPY (Buffer to URAM)	Loads Buffer into iUP URAM	(iUP-201 only)
COPY (URAM to Buffer)	Loads iUP URAM data into the Buffer	(iUP-201 only)

Figure 2. iPPS Command Summary

iUP-200 On-Line System Configuration

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Off-Line System

While capable of performing all the on-line functions, the iUP-201 allows program editing, PROM duplication, and program verification independent of the host system. In addition to the hardware components included as part of the iUP-200, the iUP-201 contains a 24-character alphanumeric display, full HEX and 11-function keypads, and 16K bytes of user RAM (URAM) expandable to 32K bytes. This expansion provides memory needed to store data for PROMs exceeding 16K bytes (128K bits) in size. Figure 3 illustrates the iUP-201 keyboard and display.

The two logical devices accessible during off-line operation are the PROM device and iUP-201 RAM. Typical operation would entail copying the data from a PROM (or ROM) into iUP RAM, modifying this data in RAM, and programming the modified data back into a PROM device. The address range of the needed RAM is automatically determined by the iUP when PROM type selection is made.

Figure 4 summarizes the off-line commands.

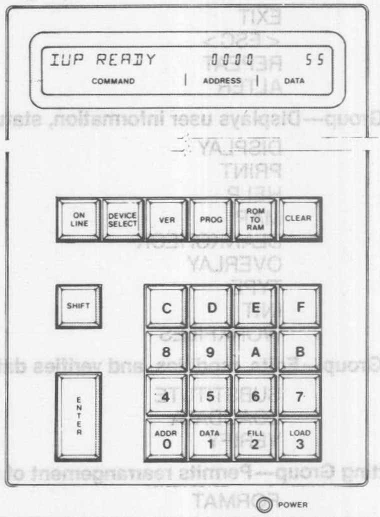

Figure 3. iUP-201 Keyboard and Display

Key	Function
ON LINE	Selects either the on-line or the off line operation. When on-line, all other function keys are disabled.
DEVICE SELECT	Selects the PROM type when a Personality Module capable of programming multiple devices is used. The selected device is indicated by an adjacent LED on the installed module.
VER	Verifies the contents of the installed PROM device with that of the iUP RAM. The iUP display indicates address and the 2's complement of any expected vs. actual mismatch.
PROG	Performs a device Blank Check and then programs the target PROM with data from iUP RAM. If Blank Check fails, pressing PROG again will perform a stuck bit check to further verify PROM/Program compatibility.
ROM TO RAM	Loads the iUP RAM with the data from the PROM device installed in the Personality Module.
CLEAR	Terminates the current off-line function, clears a user entry, or restores the display after an error condition.
ENTER	Pressing the ENTER key transfers information from the iUP display (addresses or data) into URAM.
SHIFT ADDR 0	Pressing the shift key and ADDR/0 key selects the address field for keypad entry.
SHIFT DATA 1	Pressing the shift key and DATA/1 key selects the data field for keypad editing and entry.
SHIFT FILL 2	Pressing the shift key and FILL/2 key selects the fill function, which allows a contiguous section of RAM locations to be loaded with a constant.
SHIFT LOAD 3	Pressing the shift key and LOAD/3 initiates a download of Intel hexadecimal data from any development system with an RS-232C port.

Figure 4. Off-Line Command Summary

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SYSTEM DIAGNOSTICS

Both the iUP-200 and iUP-201 include self-contained system diagnostics that provide verification of system operation and aid the user in fault isolation. Diagnostics are performed on the power supply, CPU, internal firmware ROM, internal RAM, timer, and on the iUP-201 keyboard and URAM. In addition, tests are made on any Personality Module installed in the programmer the first time the module is accessed. They include tests on the power select circuitry and the 2K of module firmware. Easy to read status messages are provided on the development system display in the on-line mode and the iUP-201 display in the off-line mode.

PERSONALITY MODULES

The iUP-200 and iUP-201 interface with a selected PROM (or ROM) through an associated Personality Module. These modules contain all of the hardware and firmware needed to read and program a family of Intel devices. Each module is a single molded unit, front panel inserted on either programmer. No additional adapters or sockets are needed. Figure 5 lists the available modules.

iUP-F27/128 - E²/EPROM Personality Module capable of reading and programming the 2716, 2732, 2732A, 2764, 27128, 2815, and 2816.

iUP-F87/51 - MICROCONTROLLER Personality Module capable of reading and programming the 8748, 8748H, 8048, 8749, 8049, 8750, 8050, 8751, and 8051.

iUP-F87/44 - PERIPHERAL Personality Module capable of reading and programming the 8741A, 8041A, 8742, 8042, 8744, 8044, and 8755A.

iUP-F36/32 - BIPOLAR Personality Module capable of reading and programming the 3628, 3632, 3632A, 3636, 3636B, and 3624.

Figure 5. iUP Personality Modules

Interfaces

Each personality module, an example is shown in Figure 6, interfaces with the programmer through a 41-pin connector. Module firmware is uploaded into iUP RAM and executed by the onboard 8085A processor. This firmware contains routines needed to Read and Program a number of PROMs. In addition, the personality module sends specific information regarding the selected PROM to the iUP to aid in performing PROM device integrity checks.

Operational status is indicated through individual LEDs on each module. A column of device selection LEDs indicate which PROM device type the user has selected. After device selection, an LED below each socket (on modules containing more than one socket) indicates the socket to be used. A red indicator light (Hot Socket) warns the user when power is being supplied to the selected device.

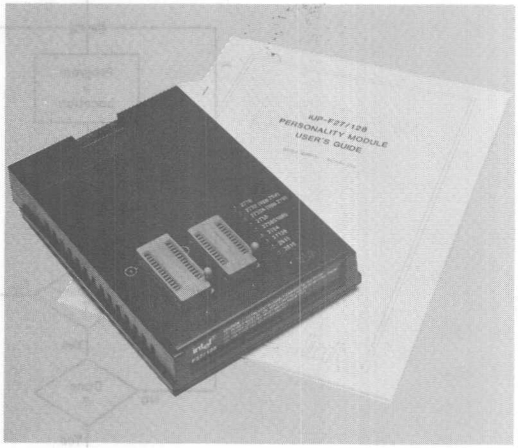

Figure 6. iUP-F27/128

Device Integrity Checks

In addition to the iUP system self-tests, each Personality Module contains diagnostics in firmware that perform selected PROM tests and indicate status. These tests are performed in both the on-line and off-line modes. A PROM installation test is performed to insure the device is installed in the module correctly and the ZIF socket is closed. A PROM Blank Check is

performed to determine whether a device is in its erased state. The iUP automatically determines whether this erased state is all zeros or all ones. A stuck bit check is performed when a PROM is found to be not blank. This test determines which bits are pre-programmed, compares those bits against the program to be loaded, and allows programming to continue if they match. As with the system self-tests, easy to read status messages are provided. All of the PROM device integrity checks, with the exception of the installation test which occurs automatically any time an operation is selected, can be invoked by the user.

Figure 7 illustrates a typical on-line and off-line programming sequence.

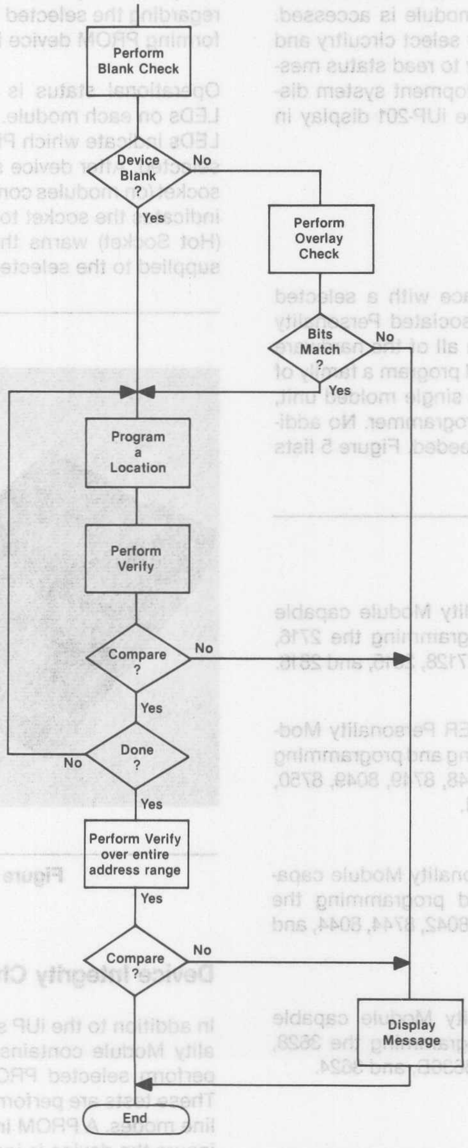

Figure 7. iUP Programming Sequence

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iUP-200/201 SPECIFICATIONS

Control Processor

Intel 8085A Microprocessor
6.144 MHz Clock Rate

Memory

RAM—2.3K bytes Static
ROM—8K bytes EPROM

Interfaces

Keyboard—16 character Hexadecimal and 11-function keypad (iUP-201 only)
Display—24 Character Alphanumeric (iUP-201 only)

Software

Monitor—System Controller in pre-programmed EPROM
iPPS—Intel PROM Programming Software utility on supplied diskette

Physical Characteristics

Depth—15 inches (38.1 cm)
Width—15 inches (38.1 cm)
Height—6 inches (15.2 cm)
Weight—15 lbs. (6.8 kg)

Electrical Characteristics

Selectable 100, 120, 200, or 240 Vac ± 10%; 50 - 60 Hz
Maximum power consumption—80 watts

Environmental Characteristics

Operating Temperature—10°C to 40°C
Operating Humidity—0% to 95% Relative Humidity

Reference Material

iUP-200/201 Universal Programmer User's Guide
iUP-200/201 Pocket Reference Card

PERSONALITY MODULE SPECIFICATIONS

Memory

EPROM — 2K bytes

Physical Characteristics

Width — 5.5 inches (14.0 cm)
Height — 1.6 inches (4.1 cm)
Depth — 7.0 inches (17.8 cm)
Weight — 1 lb. (.45 kg)

Electrical Characteristics

Maximum power consumption (module)—5 watts
Maximum power consumption (device)—2.5 watts
Maximum power consumption (total from iUP)—7.5 watts

Environmental Characteristics

Operating Temperature—10°C to 40°C
Operating Humidity—0% to 95% relative humidity

Reference Material

Selected Personality Module User's Guide

ORDERING INFORMATION

Part Number	Description
iUP-200	Intel On-Line Universal Programmer
iUP-201	Intel On-Line/Off-Line Universal Programmer
iUP-F27/128	E^2EPROM Personality Module
iUP-F87/51	MICROCONTROLLER Personality Module
iUP-F87/44	PERIPHERAL Personality Module
iUP-F36/32	BIPOLAR Personality Module

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